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Province of British Columbia

FRASER RIVER ESTUARY MANAGEMENT PROGRAM

SUMMARY OF MONITORING AND RESEARCH ACTIVITIES
and
PROCEEDINGS - FRASER RIVER ESTUARY WORKSHOP ON MONITORING AND RESEARCH

- 1988 -

Standing Committee on the Fraser River
Estuary Water Quality Plan

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ABSTRACT

The lower Fraser River and Estuary support large runs of salmon which are utilized in commercial, recreational and native food fisheries. In addition, the area is of major importance to migratory birds on the Pacific flyway and is extensively used for recreation. Industrial and municipal discharges, forest industry operations and agricultural activities affect the water quality of the Fraser River and may have an impact on its resources and recreational uses.

Monitoring programs which address these concerns are described in this report. Included is a review of the Fraser River Estuary Study (FRES) which had been established to develop a management plan for the Estuary. This was followed by the Fraser River Estuary Management Program (FREMP), which was established to help coordinate and improve decision making within the Estuary. Through FREMP, a Standing Committee on the Fraser River Estuary Water Quality Plan was formed. The mandate of this committee is to develop a plan which will include Water Quality Objectives, a coordinated monitoring program and document an acceptable arrangement for enforcement. The planned activities of this committee for 1989 are described.

This report contains a review of current monitoring and research activities in the FREMP study area. Questionnaires were sent to individuals actively working in the area. The information obtained is presented in cross referenced tables describing general study information, and the details of sediment, water chemistry, biota and bioassay studies.

The final section of this report presents the Proceedings from the February, 1988 Workshop on Monitoring and Research.

ACKNOWLEDGEMENTS

The Committee wishes to thank all those who responded to the questionnaire and provided information on their research and monitoring activities in the Fraser Estuary. We also thank Betsy Gordon for drafting and Bev Defehr for word processing.

TABLE OF CONTENTS

	PAGE NO.
Members of the Standing Committee on the Fraser River Estuary Water Quality Plan	i
Abstract	ii
Acknowledgements	iii
Table of Contents	iv
List of Tables	v
List of Figures	v
I. Summary of Monitoring and Research Activities - 1988	
1.0 Introduction	1
1.1 Fraser River Estuary Study (FRES)	2
1.2 Fraser River Estuary Management Program (FREMP)	2
1.3 Environmental Review Committee	3
1.4 Standing Committee on the Fraser River Estuary Water Quality Plan	4
2.0 Summary of Activities	5
2.1 Sediments	5
2.2 Water Chemistry	6
2.3 Biota	6
2.4 Bioassays	6
2.5 Evaluation of Sampling Duplication	6
2.6 Conclusions	7
3.0 Literature Cited	8
II. Proceedings - Fraser River Estuary Workshop on Monitoring and Research	33

LIST OF TABLES

		PAGE NO.
Table 1	Tasks for 1987 - Standing Committee on the Fraser River Estuary Water Quality Plan	9
Table 2	Project Cross Reference	10 - 14
Table 3	Summary of Questionnaire Information: General	15 - 21
Table 4	Summary of Questionnaire Information: Sediments	22 - 24
Table 5	Summary of Questionnaire Information: Water Chemistry	25 - 28
Table 6	Summary of Questionnaire Information: Biota	29 - 30
Table 7	Summary of Questionnaire Information: Bioassays	31

LIST OF FIGURES

Figure 1	FREMP Committees	32
Figure 2	Monitoring in the Fraser River Estuary (1988 Questionnaire Information)	Pocket on Back Cover

I. SUMMARY OF MONITORING AND RESEARCH ACTIVITIES - 1988

1.0 INTRODUCTION

The Fraser River rises in the Rocky Mountains, drains an area of approximately 230,000 square kilometres, and flows 1400 kilometres to its outlet in the Strait of Georgia near Vancouver, British Columbia (Figure 1). At New Westminster, the Fraser River main stem divides to form two major channels, the North Arm and Main Arm, which carry 15 and 85 percent of the river flow, respectively. The lower portion of the Fraser River is tidal, with flow reversal extending as far upstream as Mission during the winter period of low river discharge. During this low flow period, a saltwater wedge from the Strait of Georgia can penetrate upstream as far as New Westminster. During high flow in May to July, a heavy concentration of suspended sediment is transported downstream, contributing to the aggradation of river channels and the delta-front.

The Fraser River Estuary supports many activities which may compete for use of the aquatic environment. The salmon runs on the Fraser River are among the largest in the world, with major commercial catches of all five Pacific species, important native food fisheries, and a significant sports fishery. The Fraser Delta is also a major resting and feeding area for migratory birds on the Pacific flyway. The Fraser River Estuary and Delta support the many forms of aquatic life at lower trophic levels which fish, birds, and other wildlife utilize as food. The Estuary is also used extensively for recreation, including boating, hunting, bird-watching, hiking, and swimming.

The Fraser River Estuary is a zone of intense urban and industrial activity resulting in many influences on the aquatic ecosystem. Industrial effluents and landfill leachates are discharged either directly to the river or indirectly through municipal outfalls. The lower Fraser River and Sturgeon Bank receive municipal wastewater which has undergone primary treatment. In addition, the Estuary receives stormwater and combined sewer overflows (periodic dicharges of mixed, untreated sewage and stormwater). The river is dredged frequently and is a major transportation corridor. Log booms are transported and stored along the shores. Several sawmills, lumber dipping and storage operations and pulp and paper mills are located along the shoreline. The water of the Fraser River is also used by industry as process and cooling water. Additionally, intensive agricultural activities require water for irrigation and produce runoff containing pesticides and fertilizers which enter the river. The lower Fraser River is not used as a domestic water supply because supplies of higher quality exist in the Coast Region watersheds to the north.

The many resource based activities which occur along the Fraser today require that the water quality of the river be maintained or improved. The Fraser River Estuary Study (FRES) and the Fraser River Estuary Management Program (FREMP) were both initiated to address these and resolve conflicting activities and ensure maintenance of the aquatic environment.

1.1 THE FRASER RIVER ESTUARY STUDY

In 1977-78, the Canada/British Columbia FRES was established to develop a management plan for the Estuary. As part of Phase I of FRES, a Water Quality Work Group was established which published 16 technical and ancillary reports on water quality, and a summary report (Water Quality Work Group 1979). Conclusions were made on the general water quality of the river, discharge abatement measures were recommended, and recommendations were prepared for water quality monitoring.

Phase II of FRES (1979-82) focussed on the development of a proposed management program for the Fraser River Estuary. As part of Phase II, a Federal/Provincial committee was formed, which designed a monitoring program titled: Fraser River Estuary Monitoring, A Recommended Approach (Working Committee on Fraser River Estuary Monitoring 1984). Concurrent to this process, the B.C. Ministry of Environment developed provisional Water Quality Objectives in reports titled: Fraser-Delta Area, Fraser River Sub-basin from Kanaka Creek to the Mouth, Water Quality Assessment and Objectives (Swain and Holms 1984), and Boundary Bay and its Tributaries, Water Quality Assessment and Objectives (Swain and Holms 1988).

1.2 THE FRASER RIVER ESTUARY MANAGEMENT PROGRAM

The Phase II Fraser River Estuary Study Report: A Living River by the Door (Fraser River Estuary Study 1982) proposed a management program for the Fraser River Estuary. A review committee obtained public and government input to the approach and prepared the report titled: An Implementation Strategy for the Fraser River Estuary Management Program (Fraser River Estuary Management Program Review Committee 1984), which completed FRES. This report formed the basis for the signing of a Federal-Provincial agreement on October 10, 1985, initiating FREMP.

The Management Program builds upon past achievements under FRES, through adoption of common objectives and coordination of activities among agencies. One of the major goals of the Management Program is to "maintain ambient water quality levels in the Fraser River, outer estuary, and Boundary and Semiahmoo Bays that will ensure the preservation of fisheries and wildlife and, where suitable, provide for water contact recreation".

1.2 THE FRASER RIVER ESTUARY MANAGEMENT PROGRAM (cont'd)

The Estuary is defined by the Management Program to include the land and water outside the boundary of the dykes (wetted side), between Kanaka Creek and the outlet of Pitt Lake in the east, the seaward limit of Sturgeon and Roberts Banks to the west, Point Grey to the north and the international boundary to the south, including Boundary and Semiahmoo Bays.

A major objective of FREMP is to improve management decisions by having them made within an estuary-wide context and by providing all agencies involved in the estuary with an opportunity to participate. Although it would be convenient to identify a single management plan, the existing complexity of jurisdictions and relationships among agencies has resulted in the linking of several plans and activity programs, each under the jurisdiction of an appropriate lead agency and all overseen by the Management Committee (Figure 1).

The Management Committee Executive is responsible for organization and administration. It sets funding levels, maintains a Secretariat office in New Westminster, develops interagency committee initiatives, develops and approves terms of reference for activity programs, sets program priorities, and oversees the distribution of information to the public.

Eight major activities in the Estuary have been identified which involve more than one level of government and hence require coordinated management. Activity Program Work Groups comprised of agency representatives and user groups are examining these activities and developing guidelines on how they should be managed. Guidelines for preparing each of these Activity Programs were proposed in the report: An Implementation Strategy for the Fraser River Estuary Management Program (Fraser River Estuary Management Program Review Committee 1984), with specific terms of reference being developed by each of the Work Groups.

In order to improve current approaches to water quality management in the Estuary and the review of projects, the Management Committee established two key Committees: The Standing Committee on the Fraser River Estuary Water Quality Plan (Section 1.4) and the Environmental Review Committee (Section 1.3)

1.3 ENVIRONMENTAL REVIEW COMMITTEE

The Fraser River Estuary Management Program is committed to developing a system that provides thorough and efficient review of proposed projects and activities in the estuary. A coordinated project review process was established in January 1986 to achieve this goal, and is described in the publication A Guide to the Coordinated Project Review Process (Project Review

1.3 ENVIRONMENTAL REVIEW COMMITTEE (cont'd)

Work Group 1987). The Environmental Review Committee, comprised of Environment Canada, Department of Fisheries and Oceans, and B.C. Ministry of Environment, is responsible for reviewing comments from the various environmental agencies. It determines if further environmental review is required, advises the lead agency of any environmental concerns, accepts or rejects proposals, and makes recommendations on the environmental conditions under which a project may proceed.

1.4 STANDING COMMITTEE ON THE FRASER RIVER ESTUARY WATER QUALITY PLAN

Through FREMP a Standing Committee on the Fraser River Estuary Water Quality Plan has been formed, with three provincial and three federal representatives, and one representative from the Greater Vancouver Regional District. **The purpose of the committee is to develop a plan which will include ambient Water Quality Objectives for the study area, a coordinated monitoring program and documentation of an acceptable arrangement for enforcement. The overall purpose for the plan is to maintain and, where possible, improve the environmental quality of the Estuary.**

The duties of the Standing Committee also include advising the Management Committee Executive on water quality matters, providing a Status Report on Water Quality at regular intervals and advising on procedures for public input and public information.

The Standing Committee has completed several tasks since the last Research and Monitoring Report, published in September, 1987 (Standing Committee on the Fraser River Estuary Water Quality Plan 1987a). The first Fraser River Estuary Status Report on Water Quality was produced in December 1987, providing an overview of current environmental quality (Standing Committee on the Fraser River Estuary Water Quality Plan, 1987). In February, 1988 the second annual Workshop on Research and Monitoring was held at which scientists currently working in the Estuary discussed recent findings and current and planned future studies. The Standing Committee participated in the Fraser River Festival held in June 1988 with a public education display on environmental monitoring activities in the estuary and a review of committee activities.

A list of Standing Committee tasks and a schedule for the year 1989 are presented in Table 1. Two main activities are scheduled for the year: 1) completion and release of the Water Quality Plan, and 2) conducting and reporting on the third annual Research and Monitoring Workshop.

2.0 SUMMARY OF ACTIVITIES

Questionnaires regarding current (1987-1988) research and monitoring programs were sent to those who were actively working in the estuary. Tables 2 to 7 describe the results of these questionnaires.

Table 2 provides a cross reference to the subsequent tables. The entry number in the first column of Table 2 is common to the monitoring sites shown on Figure 2 and to entries in Tables 3 to 7. These Tables contain information on specific projects, the project rationale, and the environmental compartments.

Table 3 provides general information for each project, including project timing, descriptions of study areas, other involved parties, laboratories used, characteristics measured, data storage, committed resources, whether descriptions of modelling and pathways studies are available and whether publications are planned, pending or in press.

More specific information is provided in Tables 4 to 7 on sediments, water chemistry, biota, and bioassays, respectively. The information for each environmental compartment is summarized below.

A total of 32 replies to the questionnaire were received. Some studies addressed single environmental compartments while others involved various combinations of compartments (Table 2). Twelve of the 32 studies involved sediments, 19 water, 10 biota and 7 used bioassays. The B.C. Ministry of Environment was the Supporting Agency for 13 studies, while Environment Canada and the Greater Vancouver Regional District conducted 4 each. The federal Department of Fisheries and Oceans reported 5 studies.

2.1 SEDIMENTS (Table 4)

Bed sediments were investigated in 10 of the 12 reported studies and suspended sediments in 4 studies. Areas adjacent to the Iona deep sea outfall, Sturgeon Bank, Boundary Bay and the Main Stem above New Westminster were most intensively sampled. Bed sediment studies were done as far upstream as Douglas Island.

Metal and organic contaminant analyses were reported for most of the sediment studies. Two dealt specifically with physical aspects of the sediments.

2.2 WATER (Table 5)

Nineteen studies on water chemistry were reported on the questionnaires for the current year. Most of these were in the Main Arm and North Arm of the Fraser and in Boundary Bay. Those in the Fraser were most frequently done to address effects of specific discharges.

As was the case last year, the largest number of locations sampled for water quality were associated with monitoring bathing beaches for fecal coliform contamination.

Most of the water chemistry studies include measurements of metals and/or organic contaminants, with none being done strictly for the physical parameters of salinity, temperature and conductivity. In 6 studies, water monitoring is combined with sediment work and, in 5 studies, with bioassays.

2.3 BIOTA (Table 6)

Monitoring of biota was referred to in 10 studies. In these, macrophytes, invertebrates, clams, oysters and fish were investigated for biological uptake of metals and organic contaminants. Most of the work on biota occurred on Roberts and Sturgeon Banks, Boundary Bay and in the Main and North Arm of the Fraser River.

2.4 BIOASSAYS (Table 7)

Six bioassay studies were reported, 4 of which used trout and 2 used invertebrates. One bioassay was done using sediment extracts. The remainder focused on leachates and effluents.

2.5 EVALUATION OF SAMPLING DUPLICATION

Results of the previous questionnaire indicated no significant overlap in monitoring programs. This is also true for studies reported in this year's questionnaires.

Studies in the Fraser Estuary are being done to address a variety of questions. They generally differ with respect to the timing and location of field sampling and in the combination of environmental compartments and contaminants monitored.

2.6 CONCLUSIONS

Environmental monitoring and specific research programs are continuing at a significant level in the Fraser Estuary. The greatest effort is currently going into the measurement of metals and organic contaminants in all environmental compartments. This shift from conventional parameters will contribute to badly needed information on the fate and biological effects of contaminants in the Fraser. Monitoring of fecal coliform contamination continues to be done throughout the Estuary.

3.0 LITERATURE CITED

Fraser River Estuary Management Program Review Committee. 1984. An Implementation Strategy for the Fraser River Estuary Management Program. Environment Canada, B.C. Ministry of Environment, 1980. IV, 45 p.

Fraser River Estuary Study. 1982. A Living River by the Door. A Proposed Management Program for the Fraser River Estuary. Fraser River Estuary Study, Phase II. Government of Canada and Province of British Columbia. Victoria, 64 p.

Swain, L.G. and G.B. Holms. 1984. Fraser-Delta Area Fraser River Sub-basin From Kanaka Creek to the Mouth, Water Quality Assessment and Objectives. Resource Quality Section, Water Management Branch, B.C. Ministry of Environment.

Holms, G.B. and L.G. Swain. 1988. Fraser-Delta Area, Boundary Bay and Tributaries, Water Quality Assessment and Objectives. Resource Quality Section, Water Management Branch, B.C. Ministry of Environment and Parks.

Project Review Work Group. 1987. A Guide to the Coordinated Project Review Process. Fraser River Estuary Management Program. 35 p

Standing Committee on the Fraser River Estuary Water Quality Plan. 1987a. Summary of Monitoring and Research Activities. September 1987. 43 p

Standing Committee on the Fraser River Estuary Water Quality Plan. 1987 b Status Report on Water Quality in the Fraser River Estuary - 1987. 103 p.

Water Quality Work Group. 1979. Fraser River Estuary Study: Water Quality. Summary Report. Government of Canada and Province of British Columbia. 176 p.

Working Committee on Fraser River Estuary Monitoring. 1984. Fraser River Estuary Monitoring, A Recommended Approach. Government of Canada and Province of British Columbia. 43 p.

These reports can be requested through the FREMP office, at 708 Clarkson Street, New Westminster, B.C. V3M 1E2 Telephone: (604)525-1047.

Table 1 - Tasks for 1989 - Standing Committee on the Fraser River Estuary Water Quality Plan

Task	Target Date
Third Annual Monitoring and Research Workshop	February
Water Quality Plan - Public Review	May
Water Quality Plan - Final	June
Report - Third Annual Monitoring and Research Workshop and Questionnaire Responses	July

TABLE 2
PROJECT CROSS REFERENCE

ENTRY	SUPPORTING AGENCY	CONTACT	TELEPHONE	PROJECT TITLE	PROJECT RATIONALE	SEDIMENTS (Table 4)	WATER CHEMISTRY (Table 5)	BIOTA (Table 6)	BIOASSAYS (Table 7)	(OTHER DETAILS) (Table 3)
1	DOE Environmental Protection	P. Krahn	666-3057	Characterisation of Ship Building And Repair Industry	To determine chemical use patterns, waste generation and disposal, environmental pathways.	X	X			
2	B.C. Ministry of Environment	D. Walton L. Swain	584-8822 387-9518	Mitchell Island Stormwater Study	To characterize drainage entering the river from this centre of chlorophenate usage.	X	X			X
3	B.C. Ministry of Environment	M. Gow L. Swain	584-8822 387-9518	Water Chemistry Monitoring (1988/1989)	To assess if Water Quality Objectives are met in the main river channels.		X			X
4	B.C. Ministry of Environment	L. Swain D. Walton	387-9518 584-8822	Sediment Quality in the Lower Fraser River	To compliment FRHC sediment studies by sampling additional sites in the three main channels.	X				X
5	B.C. Ministry of Environment	L. Swain D. Walton	387-9518 584-8822	Fraser River Estuary Monitoring. Year 2-Sediments Year 3 - Biota	To determine contaminant concentrations.	(1987/1988)	(89-90)	(88-89)		X
6	B.C. Ministry of Environment	B. Moore	584-8822	Annacis Woodwaste Leachate Survey	To determine if Annacis Highway roadbed woodwaste leachate impacts significantly on trout eggs.		X		X	X
7	B.C. Ministry of Environment	L. Swain D. Walton	387-9518 584-8822	Water Quality Objectives-Kanaka Creek to mouth of Fraser River (1987/1988)	Assess North Arm water quality under wet and dry conditions.		X			X

TABLE 2 (Continued)
PROJECT CROSS REFERENCE

ENTRY	SUPPORTING AGENCY	CONTACT	TELEPHONE	PROJECT TITLE	PROJECT RATIONALE	SEDIMENTS (Table 4)	WATER CHEMISTRY (Table 5)	BIOTA (Table 6)	BIOASSAYS (Table 7)	(OTHER DETAILS) (Table 3)
8	B.C. Ministry of Environment	L. Swain D. Walton	387-9518 584-8822	Water Quality Objectives-Kanaka Creek to mouth of Fraser River (1987/1988)	Assess Fraser River water quality in the three reaches		X			X
9	B.C. Ministry of Environment	L. Swain D. Walton	387-9518 584-8822	Water Quality Objectives - Kanaka Creek to mouth of Fraser River	Assess water quality near specific discharges.		X			X
10	B.C. Ministry of Environment	B. Moore	584-8822	Belkin Paperboard Dissolved Oxygen Study	To determine effect of effluent on dissolved oxygen during worst case low-flow conditions to measure chronic toxicity of the effluent.		X		X	X
11	B.C. Ministry of Environment	B. Moore	584-8822	Domtar PCP Survey	To determine the impact of chlorinated phenols leaving the site on fish and benthic organisms.		X		X	X
12	B.C. Ministry of Environment	B. Moore	584-8822	Koppers PCP Survey	To determine the location of greatest PCP seepage to the river and its impact on fish and benthic organisms.	X	X		X	X
13	B.C. Ministry of Agriculture and Food B.C. MOE	M. Drichuyzen N. Nagpal	576-2911 387-9507	Boundary Bay Water Control Project	To study all aspects of water control relative to agriculture or environment.		X			X
14	B.C. Ministry of Health	L. Copeland	594-0441	Bathing Beach Monitoring	To check for fecal coliforms during summer at bathing beaches to ensure standards are met.		X			X

TABLE 2 (Continued)
PROJECT CROSS REFERENCE

ENTRY	SUPPORTING AGENCY	CONTACT	TELEPHONE	PROJECT TITLE	PROJECT RATIONALE	SEDIMENTS (Table 4)	WATER CHEMISTRY (Table 5)	BIOTA (Table 6)	BIOASSAYS (Table 7)	(OTHER DETAILS) (Table 3)
15	UBC	M. Church	228-3444	Channel Stability and Sedimentation along the lower Fraser River	To determine the sediment budget between Hope and the sea and its effect on channel stability.	X				X
16	North Fraser Harbour Commission	G. Colquhoun	273-1866	North Fraser Harbour Environmental Plan	To develop a proactive, cooperative environmental management plan for port development/habitat conservation.		X			X
17	Neptune Aquafarms International Ltd.	G. Vigers	986-4331	Boundary Bay, Initial Water Quality Testing	To determine whether Boundary Bay water quality will now meet federal and provincial bacterial water quality standards for shellfish growing.	X	X	X		X
18	Geological Survey of Canada	J. Luternauer	666-0788	Marine Delta Sedimentation	To determine sediment budget delta front stability, development induced erosion, sediment dispersal patterns, sedimentation rates.	X				X
19	DOE, Inland Waters.	F. Mah	666-8000	Concentration of Chlorophenols in precipitation in the Fraser River Estuary	To determine atmospheric input of chlorophenols to the aquatic environment.		X			X
20	DOE, Inland Waters	L. Churchland S. Sheehan	666-6019 666-8007	Toxic Substances in Suspended Sediments of the Lower Fraser River	To determine sampling methods and levels of metals and toxic organic contaminants in suspended sediments.	X				X

TABLE 2 (Continued)
PROJECT CROSS REFERENCE

ENTRY	SUPPORTING AGENCY	CONTACT	TELEPHONE	PROJECT TITLE	PROJECT RATIONALE	SEDIMENTS (Table 4)	WATER CHEMISTRY (Table 5)	BIOTA (Table 6)	BIOASSAYS (Table 7)	(OTHER DETAILS) (Table 3)
21	DFO, Institute of Oceans and Sciences	T.S. Murty	356-6311	Numerical Model Studies of Fraser River Plume in the Strait of Georgia	To develop a model GF 8 which uses an implicit scheme to allow longer running periods.					X
22	DFO, Fisheries Research Branch	E. Chromanski	666-7508	Residence and Interactive Ecology of Non-salmonids in the Lower Fraser River Estuary	To examine competitive interactions and to determine length of residence of non-salmonids used to monitor contaminant levels in estuarine habitats.			X		X
23	DFO, Biological Sciences Branch	C.D. Levings	666-7915	Chinook Production and Residency	To obtain data on chinook residency, migration, feeding and food supplies.			X		X
24	DFO, Biological Sciences Branch	C.D. Levings	666-7915	Evaluation of Restored Fish Habitat	To evaluate fish use and insect emergence.			X		X
25	DFO, Physical and Chemical Sciences Branch	I.H. Rogers	666-7912	Uptake of Toxic Chemicals in Resident Benthic Fish in the Fraser Estuary	To determine uptake of contaminants by benthic feeding fish.			X		X
26	DFO, Biological Sciences Branch	I. Birtwell G. Kruzynski	666-7909 666-7913	Effects of Contaminents on Eulachons	To integrate organic contaminents during migration through the Fraser Estuary.			X		X
27	DOE, Environmental Protection	M. Pomeroy	666-2937	An Investigation into Toxic Chemical Accumulation in Vascular Plants of the Fraser River Estuary	To determine uptake of contaminents and usefulness of vascular plants as indicators.	X		X		X

TABLE 2 (Continued)
PROJECT CROSS REFERENCE

ENTRY	SUPPORTING AGENCY	CONTACT	TELEPHONE	PROJECT TITLE	PROJECT RATIONALE	SEDIMENTS (Table 4)	WATER CHEMISTRY (Table 5)	BIOTA (Table 6)	BIOASSAYS (Table 7)	(OTHER DETAILS) (Table 3)
28	DOE, Environmental Protection	M. Pomeroy A. Colodey	666-2937 666-2883	Metals and Organic Contaminants in Sediments and Biota at Sturgeon and Roberts Bank	To study spatial distribution and biological uptake of selected contaminants.	X		X		X
29	Greater Vancouver Regional District	R. Jones	432-6429	Receiving Water Quality, Main Arm, Fraser River	To determine impacts from discharges from Annacis Island and Lulu Island STP'S on Main Arm water quality.		X			X
30	Greater Vancouver Regional District	R. Jones	432-6429	Sewage Treatment Plant Effluent Discharges	To monitor characteristics of discharges from Annacis Island and Lulu Island STP's.		X (Effluent)		X	X
31	Greater Vancouver Regional District	R. Jones	432-6429	Fraser River, North Arm, Routine Monitoring	To assess possible pollution sources affecting Pt. Grey and English Bay Beaches.		X			X
32	Greater Vancouver Regional District	R. Jones	432-6429	Iona Deep Sea Outfall Monitoring	To conduct 2nd year (1987) pre-discharge monitoring of Iona Deep Sea Outfalls and characterization of effluent discharge.	X	X	X	X	X

TABLE 3
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
1	July 1988 March 1989	To be determined	N/A	Environmental Protection	Metals, organics	Files	N/A	N/A	6	4 000	Planned
2	Jan. 1988-	Mitchell Island, specifics to be determined from site study	consultant yet to be selected	B.C. MOE Environmental Laboratory	PCP, TTCP, TCP, metals	SEAM files	N/A	N/A	unknown	unknown	Not Stated
3	1987-?	Main Stem, Main Arm, North Arm	Not Stated	B.C. MOE Environmental Laboratory B.C. Ministry of Health Cantest	Cu, Pb, Zn, pH, SS, D.O., Temperature, ammonia, fecal coliforms	SEAM files	N/A	N/A	1.0	6 000	1 Planned
4	Jan. 1987 (completed)	Lower Fraser River	R. Kistritz and Assoc.	B.C. MOE Environmental Laboratory	PCB's, PCP, TTCP, As, Al, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pb, Se, St, Vd, Zn, P	SEAM files, FRHC	N/A	N/A	0.1	14 000	In publication for Entry 5
5	April 1987- March 1988 (completed)	Main Stem, Main Arm, North Arm	FRHC, R. Kistritz and Assoc., R.Harder & Assoc.	B.C. MOE Environmental Laboratory ASL Laboratories	Metals, PCB's, chlorinated phenols, TOC, organochlorine scan	SEAM files	N/A	N/A	---	100 000 per fiscal year	Published March 1988 (sediments)

TABLE 3 (Continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
6	May 1987-Aug. 1987	Fraser River-Main Arm	N/A	B.C. MOE Environmental Laboratory, field bioassay	Resin acids, acidity, pH, specific conductivity, organic N, TOC	Not Stated	N/A	N/A	1.0	2,600 plus salary	Planned
7	Sept. 1987-Feb. 1988	North Arm	N/A	B.C. MOE Environmental Laboratory	Cu, Pb, Zn, Cr, fecal coliforms, NFR, pH, D.O., Temperature, ammonia	SEAM	N/A	N/A	0.3	6,300 plus salary	Planned
8	Dec. 1987-March 1988	Main Stem, Main Arm, North Arm	N/A	B.C. MOE Environmental Laboratory	Cu, Pb, Zn, fecal coliforms, NFR, pH, D.O., Temperature, ammonia	SEAM	N/A	N/A	0.25	1,800 plus salary	Planned
9	July 1987-Aug. 1987	Annacis, Lulu, Langley, STP's, Scott Paper	K.Hutton	B.C. MOE Environmental Laboratory	Cu, Pb, Zn, fecal coliforms, Temperature, pH, D.O., ammonia, chlorinated phenols	SEAM	N/A	N/A	Not Stated	8,640 plus salary	Planned
10	Oct. 1987-April 1988	Belkin Paperboard	N/A	B.C. MOE Environmental Laboratory	BOD, chlorophenols	Not Stated	N/A	N/A	0.8	2,800 plus salary	Planned
11	May 1987-Nov. 1987	North Arm, Domtar Area	N/A	B.C. MOE Environmental Laboratory	PCP, creosote, fish tissue chemistry, SWEP bioassay, in "situ" fish bioassay	Not Stated	N/A	N/A	1	7,500 plus salary	Planned

TABLE 3 (Continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
12	Oct. 1987-Jan. 1988	North Arm, Koppers site	N/A	B.C. MOE Environmental Laboratory	PCP, creosote	--	N/A	N/A	1.3	12,000 plus salary	Planned
13	Ongoing	Near Crescent Slough	--	B.C. MOE Environmental Laboratory	pH, Sp. Cond., Total and ortho phosphate, TKN, NH_3, NO_3	SEAM	N/A	N/A	0.5	7,000	Planned
14	Ongoing	Semiahmoo Bay, Crescent Beach, Centennial Beach, Boundary Bay Beach, Tsawwassen Beach, Ferry Causeway	--	B.C. Ministry of Health Laboratory	Fecal coliforms	Files	N/A	N/A	--	---	---
15	Ongoing	Main Arm downstream of Deas Island to Sandheads	GSC, from 1988 Water Survey of Canada to 1987	UBC Geography	Texture Size	UBC Files	N/A	N/A	87-89 5 86-87 20	 35,000 50,000	Several Published
16	Early 1988	North Arm from Queensborough Bridge to Wreck Beach	DFO	----	Surveillance observations during harbour patrols	Files	N/A	N/A	--	--	Planned
17	Sept. 1986-Dec. 1988	Boundary Bay and Tributaries	EP	EVS, A.S.L. and EP Laboratories	Metals, organics, fecal coliforms, dissolved oxygen, Temperature, salinity	Computer	N/A	N/A	1.0 (87/88) 2.0 (88/89)	10,000 (87/88) 20,000 (88/89)	Planned

TABLE 3 (Continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
18	1979-	Main channel-outer channel and delta slope	U. of Guelph, Public Works Canada	GSC laboratory	Grain size, organic content, metallic ions, sediment structure, bed forms, erosion rate, sedimentation rate	Computer Files	N/A	N/A	1.0	2,000	Planned Published
19	1987-1991	To be determined	N/A	IWD, Water Quality National Laboratory	chlorophenols in rainwater	To be determined	N/A	N/A	3 (87/88) 4 (88/89) 4 (89/90) 2 (90/91)	12,000 (87/88) 28,000 (88/89) 14,000 (89/90) 10,000 (90/91)	Planned
20	1989-	Main Stem	DFO (IOS)	IWD, Water Quality National Lab. MOE, WQB Lab. Water Survey of Canada lab.	chlorophenols, PCB's, PAH's, organic carbon, Pb, Hg, Cd, Ni, Zn, Cu, Cr, particle size	Files	N/A	N/A	1.5 (88/89)	unknown	Planned
21	Jan. 1987- Jan. 1988	Georgia and Juan de Fuca Straits	Pacific Oceans Sciences Ltd.	---	---	---	N/A	N/A	---	---	In Press

TABLE 3
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
22	April 1987-April 1988	Main Arm, North Arm	DFO, IOS	DFO, West Vancouver	Temperature, salinity, conductivity, fish population studies, stomach contents otoliths	Computer	N/A	N/A	12.0	105,000	Planned
23	March 1987-Aug. 1988	North Arm, Gravesend Reach, Queens Reach	DFO, Fisheries Branch	DFO, West Vancouver	Chinook CPUE, biomass, condition factor, feeding	VAX and PCs	Food, Webs	N/A	16	15,000 plus salary	Data Records Pending
24	March 1987-Sept. 1989	North Arm, Annacis Channel	DFO, Fisheries Branch	DFO, West Vancouver	Insect emergence, numbers, basic vegetation information	VAX and PCs	N/A	N/A	8	10,000 plus salary	Data Records Pending
25	June 1978-June 1990	North Arm, Main Arm to Port Mann	DFO, Biological Sciences Branch	DFO, West Vancouver	chlorophenols, chloroguaiacols, DDT, chlordane, PCB's	PCs	N/A	N/A	14	10,000 plus salary	Planned
26	Ongoing 1988/89	South and North Arms to New Westminster	DFO, Physical and Chemical Sciences Branch	DFO, West Vancouver	Eulachon tissues, chlorinated phenolics, PCBs, DDT, DDE, DDD, other chlorinated organics	PCs	N/A	N/A	2	2,000	In Preparation
27	Ongoing to April 1989	Marshes - Roberts and Sturgeon Banks	AIM Ecological Consultants	ASL, EP Lab		Computer	N/A	N/A	4.0	70,000	Planned

TABLE 3
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
28	June 1988-Nov. 1988 Ongoing	Roberts and Sturgeon Banks	--	EP lab		Computer	N/A	N/A	1.5	10,000	In Press
29	Ongoing	Main Arm	--	GVRD lab	T, D.O., FC, Total and S.S., Cl, Na, Ca, Cu(D) Pb(D), Zn(D), Cd(D), Cr(D), Fe(D), residual chlorine	GVRD Files	N/A	N/A	---	---	Printed Bi-Monthly Summaries
30	Ongoing	Main Arm (Annacis and Lulu STP's) Effluents	--	GVRD Lab, Beak Assoc. Consulting Ltd.	SS, COD, Sp. Cond., T, D.O., pH, BOD, MBAS, PC, O&G, Phenol, Toxicity, NH_3, TKN, NO_2, NO_3; T.P., Al, As, Cd, Cr, Cu, Fe(D), Pb, Mn, Hg, Mo, Ni, Zn, B, SO_2	Files	N/A	N/A	---	---	Printed Monthly Reports and Annual Summaries
31	Ongoing	North Arm	--	GVRD Lab	T, D.O., F.C., Sp. Cond., Salinity	Files	N/A	N/A	---	---	Printed Biweekly Reports and Annual Summary
32(a)	Ongoing	Sturgeon Bank (Iona STP effluent)	-- Ecological Consultants	Beak Consultants, GVRD	Same as entry	Files Computer	N/A	N/A	---	---	Printed Monthly Reports and Annual Summaries

TABLE 3
SUMMARY OF QUESTIONNAIRE INFORMATION:
GENERAL

ENTRY	PROJECT TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	OTHER INVOLVED PARTIES	LABORATORIES USED	CHARACTERISTICS MEASURED	DATA STORAGE	DESCRIPTION OF PATHWAYS STUDIES	DESCRIPTION OF MODELLING	RESOURCES		PUBLICATION (PLANNED, PENDING, IN PRESS)
									PERSON MONTHS	TOTAL BUDGET($)	
32(b)	Ongoing	Iona Beach, Point Grey Beaches	--	GVRD Lab	T, D.O., F.C., Salinity	Files Com-puter	N/A	N/A	--	--	Printed Summaries and Geometric Means
32(c)	1987	Sturgeon Bank - pre-discharge monitoring	--	Beak Consulants, GVRD, Cantest	See Tables 4, 5 and 6 this entry	Files	N/A	N/A	--	--	Final Report

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	TYPE OF SAMPLE	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
1	Not determined	July 88 to March 89	Not determined	Bed	Not determined	Not determined	Not determined	Metals and Organics	Not determined
2	Once	Unknown	Fraser River below Kanaka Creek, Sturgeon and Roberts Banks, Boundary Bay	Bed	4	1	Surface	PCP, TTCP, TCP, Metals	Petite Ponar Grab
4	Once	January 1987	Lower Fraser River	Bed	15	1	Surface	PCB's, PCP, TTCP, As, Al, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pb, Zn, Se, St, Vd, P.	Not Stated
5	Once	January 1987	Main Stem, Main Arm, North Arm	Bed	3	10+	Surface	Metals, PCB, CP, TOC, Particle size, Organochlorine	Grab
12	Twice	April, October	Koppers International site, U/S and D/S of barge moorage	Bed	5	1	Surface	PCP, creosote	Grab
15	Daily, Weekly	May 15- Sept. 1, 1988	Main Arm, downstream of Deas Island to Sandheads	Bed, Suspended	Not determined	Not determined	Not determined yet	Texture, Concentration	Not Stated

TABLE 4 (continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
SEDIMENTS

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	TYPE OF SAMPLE	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
17	Semi-annual	Not Stated	Boundary Bay	Suspended	5	3	+0.1 to -0.2 tidal height	Metals, organics	Mud snapper, grab samples Scoop at low tide
18	Monthly	April to October 1988	Main channel, Outer channel and delta slope	Suspended Bed	Adjacent to develop-ments	Variable	to 1m on flats, to 2m on slope	Grain size, organic content, metallic ions, sediment structure, bed forms, erosion rate, sedimentation rate	Grab, water pump, Echo sounding
20	Once	March 1989	Main Stem	Suspended	Undecided	Undecided	Undec-ided	chlorinated phenol-ics, PCB's, PAH's, organic carbon, Pb, Hg, Cd, Ni, Zn, Cu, Cr, particle size	To be determined
27	Two-year study, 3 sample periods	ending March 1989	Marsh area Sturgeon and Roberts Banks	Bed	4	3	surface	Hg, Zn, Cd, Pb, Cu, PCB, PCP, particle size, SVR	Surface - Intertidal scrape
28	Semi-annual	Jan., June	Roberts and Sturgeon Banks-Intertidal flats	Bed	10	1	surface	Particle size, SVR, metals, PCP, PCB, PAH	surface scrapes

TABLE 4 (continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
SEDIMENTS

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	TYPE OF SAMPLE	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
32(c)	Once	Sept. 1987	Sturgeon Bank	Bed	3 grabs	6	surface	Total volatile residue, Particle size, PAH's, chlorinated phenolics chlorinated hydro-carbons	Van Veen Grab

TABLE 5
SUMMARY OF QUESTIONNAIRE INFORMATION:
WATER CHEMISTRY

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE ?)	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
1	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined	Metals and Organics	Not Determined
2	Once	Unknown	To be determined	4	1	Surface	PCP, TTCP, TCP, Metals	Surface Grabs
3	Once/week for 5 consecutive weeks	December to March	Main Stem, Main Arm, North Arm	3	1	Surface	Cu, Pb, Zn, pH, SS, D.O., Temperature, ammonia, fecal coliforms	Surface Grabs
6	Unknown	April, May, June	Fraser River, Main Arm	3	1	Surface	acidity, pH, specific conductivity, organic N, TOC	Surface Grabs
7	3 wet weather, 3 dry weather	Sept. 87 - Jan. 88	North Arm	3	1	Surface	Cu, Pb, Zn, Cr, fecal coliforms, NFR, pH, D.O., TOC, NH_2, CP's	Surface Grabs
8	Once/week for 5 consecutive weeks	Dec. - Mar.	To be determined	3	1	Surface	Cu, Pb, Zn, fecal coliform, NFR, pH, D.O., T^0C, NH_3	MOE Lab, YSI meter
9	Once/week for 5 consecutive weeks	July 87 - August 87	Annacis Island, Lulu Island, Langley STPs, Scott Paper	4	3	Surface	T^0C, pH, D.O., fecal coliform, NH_3, Cu, Pb, Zn, CPs	MOE Lab, YSI meter
10	Not stated	April, October	Belkin effluent	5	1	Surface	BOD, CP for receiving H_2O and effluent	MOE Lab

TABLE 5 (continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
WATER CHEMISTRY

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
11	Once during period	May-June	Domtar, North Ditch, Nelson Creek, Fraser River	4	3	Surface	PCP, Creosote	Grab or Surface Grab
12	Twice per year	April, October	Koppers International site, Fraser R.N. Arm, alongside Koppers's tarmac	5	1	Not Reported	CPs, Creosote	MOE Lab
13	Monthly (nutrients) 2-3 year (pesticides)	Year-Round	Near Crescent Slough	5	1	N/A	TKN, NH_3, NO_3, Total & Ortho P, Sp. Cond., pH	Shallow wells
14	Once/week	June-August	Bathing Beaches	12 and at stormwater outfalls if results at beaches are high	1	Surface	Fecal Coliforms	Grab
16	Daily during patrols by Harbour Patrol	Throughout the year	Throughout North & Middle Arms	Variable	N/A	N/A	Visual observations only	N/A
17	Monthly	July 87 to December 88	Boundary Bay	10	1	Surface	Fecal coliforms, temperature, D.O. salinity	APHA A.1 modified thermometer, YSI D.O. meter, ABBE Refractometer

TABLE 5 (continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
WATER CHEMISTRY

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
19	Dependent on amount of precipi-tation	Dependent on precipitation	To be determined	Probably 4	Dependent on precipit-ation	N/A	Chlorophenols	To be developed
21	Not reported	Not reported	Straits of Georgia and Juan de Fuca including the mouth of the Fraser River	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported
29	Bimonthly	Yearly	Main Arm Fraser River	5	1	Surface	T, D.O,. FC, Total & S.S. Solids, Cl, Na, Ca, Cu(D), Pb(D), Zn(D), Cd(D), Cr(D), Fe(D), Residual Chlorine	Surface Grab, Midstream
30	Daily to monthly Dependent on character-istic	Yearly	Discharges, Annacis & Lulu STP's	2	1 Effluent Weir	N/A	S.S., COD, Sp. Cond., T, D.O., pH, BOD_5, MBAS, FC, O&G, Phenol, Toxicity, TKN, NH_3, NO_2/NO_3, T.P., Al, As, Cd, Cr, Cu, Fe(D), Pb, Mn, Hg, Mo, Ni, Zn, B, So_2	Grab or composite Dependent on characteristic
31	Biweekly	May-September	N.Arm, Fraser River	11	1	Surface	T, FC, D.O., Sp. Cond., Salinity	Surface Grab

TABLE 5 (continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
WATER CHEMISTRY

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	NO. OF LOCATIONS	SAMPLES/ LOCATION	SAMPLE DEPTHS	CHARACTERISTICS MEASURED	SAMPLING METHODS USED
32(a)	Daily to monthly dependent on character-istic	Yearly	Discharges, Iona STP effluent	1	1 (effluent)	N/A	As per Entry #	Grab or composite
32(b)	Biweekly	May to September	Point Grey and Iona Beaches	Pt.Grey - 11 Iona - 6	1	Surface	T, FC, D.O., Sp. Cond., Salinity	Surface Grab
32(c)	Three times in 1987	Freshet (1) Post-freshet (2)	Sturgeon Bank	7	2 - 3	Surface, 10 m below haloc-line, bottom	pH, conductivity, T, D.O,. FC, enterococci, NH_3 Tot.P,S.S, NO_3, S:O_2, T and D, Cd, Cu Cr, Pb, Ag, Zn, Total As and Hg. PAH's, chlorinated phenolics, chlorinated hydro-carbons.	Grab Samples, Nansen Bottles

TABLE 6
SUMMARY OF QUESTIONNAIRE INFORMATION:
BIOTA

ENTRY	FREQUENCY	TIMING	POP. STUDIES Y/N	LIFE CYCLES Y/N	BIO-ACCUMULATION Y/N	STUDY AREA (REFERENCED ON FIGURE 2)	NO. OF LOCATIONS	SPECIES @ EACH LOCATION	TISSUES	CHARACTERISTICS	SAMPLING METHODS USED
5	Once	1988-1989	N	N	N	D/S reaches of each Arm	3	Fish vary with location: pea-mouth chub, largescale sucker, northern squawfish, starry flounder, threespine stickleback, staghorn sculpin redside shiners	Yes	PCB's, CP's, metals, PAH's Phthalate oysters, organo chlorine pesticides oysters,	Surface - gil net, beach
17	Semi-annual	October and April	N	N	Y	Boundary Bay	5	Pacific Oyster	Whole Body	Fecal coliforms, metals and organics	40-50 small oysters sampled, Oct. 87 and April 88
22	Biweekly April-Aug., Monthly Sept.-March	April 87-April 88	Y	N	N	Main Arm, North Arm	8	Fish	No	Environment-Temperature, Salinity, Conductivity, Current	Beach Seine
23	Biweekly, March to September	1987 - 1988	Y	Y	N	North Arm, Main Arm, Annacis Channel	19	Fish	No	CPUE, biomass, condition factor, length	Beach Seine, Surface Trawl
24	Biweekly, March to September	1987 - 1988	Y	Y	N	North Arm, Annacis Channel	10	Emergent insects basic vegetation data	No	Numbers, marsh vegetation data	Floating Emergence Traps

TABLE 6 (continued)
SUMMARY OF QUESTIONNAIRE INFORMATION:
BIOTA

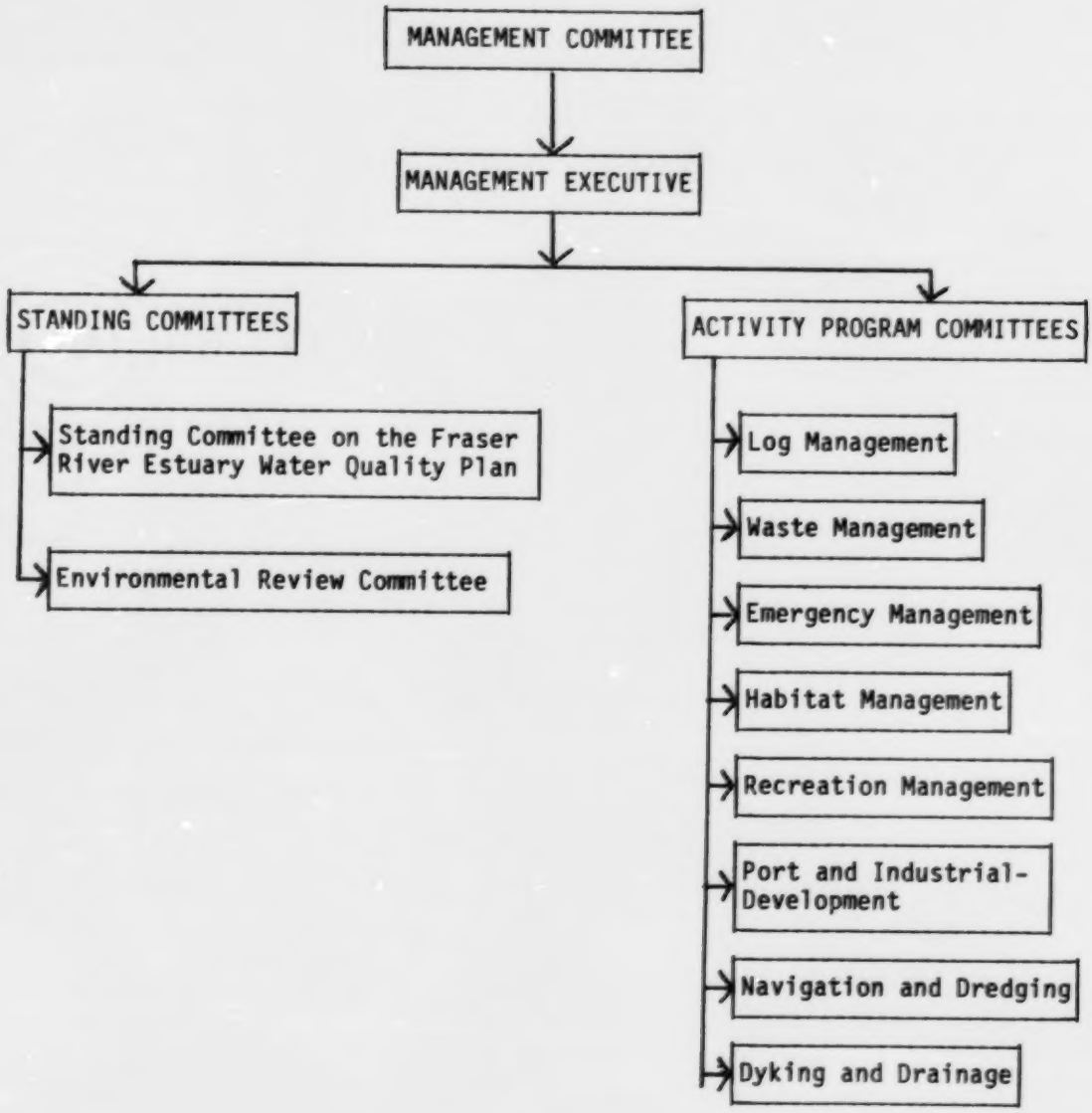
ENTRY	FREQUENCY	TIMING	POP. STUDIES Y/N	LIFE CYCLES Y/N	BIO-ACCUMULATION Y/N	STUDY AREA (REFERENCED ON FIGURE 2)	NO. OF LOCATIONS	SPECIES @ EACH LOCATION	TISSUES	CHARACTERISTICS	SAMPLING METHODS USED
25	Twice in each of two seasons	1987 - 1990	N	N	Y	North Arm, Main Stem	10	Cottids, flounder, sticklebacks	Yes	Chlorophenols, chloroguaiacols PCB's, DDE, chlordane	Beach seine
26	Fieldwork complete	1988	N	N	Y	North/South Arms to New Westminster	5	Eulachons	Yes	Chlorinated organics	Gill net
27	3 times during program	Ongoing to April 1989	N	N	Uptake by vascular plants	Marshes-Roberts and Sturgeon Banks	3	Carex, Juncus Scirpus	Plant - roots, stems, leaves, seeds	Metals, PCP, PCB	Harvest
28	2/year	June, January	N	N	Y	Roberts and Sturgeon Banks	10	Invertebrates, clams	whole	Size, species, PCP, PCB, PAH, metals	Surface grab
32	Once/year	1987 complete 2nd year	N	N	Y	Roberts and Sturgeon Banks	6	Pelagic fish, ground fish, invertebrates	dorsal muscle, liver - gall bladder, whole fish and invertebrates	Cd, Cr, Cu, Pb, Zn, As, Hg, PAH's, chlorinated phenolics, chlorinated hydrocarbons	Gill net, trawl and Vanveen grab

TABLE 7
SUMMARY OF QUESTIONNAIRE INFORMATION:
BIOASSAYS

ENTRY	FREQUENCY	TIMING	STUDY AREA (REFERENCED ON FIGURE 2)	NO. OF LOCATIONS	SAMPLING SITES/ LOCATION	LAB	SPECIES	TYPE			DESCRIPTION OF TECHNIQUE	REASON(S) FOR BIOASSAY
								FIELD, STATIC FLOW THROUGH	DURATION	LC50 LT50		
6	Not Reported	Apr/May/June	112th Street Creek, Fraser River, Main Arm	3	1	MOE Lab	Trout Eggs	Field	Not reported	Not reported	Not reported	To determine impact of leachates from roadbed & woodwaste on trout eggs
10	2	April, Oct.	N. Arm, Fraser River at Belkin Paperboard site	5	1	MOE Lab	Daphnia	Static	Not reported	Not reported	Not reported	To measure the chronic toxicity of Belkin Paperboard effluents
11	Once during period	May-June	Domtar, Nelson Creek, Fraser River	4	1		Rainbow trout	Field	Not Reported	Not Reported		To determine impact of chlorinated phenols on fish
12	2	April, Oct.	N. Arm Fraser Koppers International site	5	1	EP Lab	Daphnia, Hyalella	Static	Not reported	Not reported	Sediment extract for Daphnia	To determine max. PCP seepage to Fraser River
30	Monthly	Yearly	Annacis & Lulu STP effluents	2	1	Beak Consultants	Rainbow trout	Static	96 h	LC50	BC MOE (1982)	Permit Monitoring Requirement
32	Monthly	Yearly	Iona	1	1	Beak Consultants	Rainbow trout	Static	96 h	LC50	BC MOE (1982)	Permit Monitoring Requirement

FIGURE 1

FREMP COMMITTEE



II PROCEEDINGS - FRASER RIVER ESTUARY WORKSHOP ON MONITORING AND RESEARCH - 1988

The following are the proceedings from the Second Annual Workshop on Monitoring and Research held February 24th, 1988. Information contained in this and subsequent workshops will be used along with other material by the Standing Committee in preparation of the next Fraser River Estuary Status Report due March, 1990. Questions relating to the following abstracts should be addressed directly to the authors.

ABSTRACTS, QUESTIONS AND ANSWERS

1.0 UPDATE ON FREMP ACTIVITIES

M. McPhee, Program Co-ordinator, FREMP

M. McPhee explained how FREMP was started in 1985, and what has happened since then. He outlined the goals and objectives of FREMP and how the various program activities are oriented towards meeting those goals. One of the goals of FREMP is to promote an understanding of the Fraser River and its resources, and how these resources are managed and used. Progress in each of the Activity Programs of habitat management, log management, recreation, port and industrial development, navigation and dredging, emergency management and waste management was reviewed. The Co-ordinated Project Review Process, in operation since January 1986, was also described as being very successful in ensuring each development proposal in the estuary is adequately reviewed.

Publications to date include A Guide To The Coordinated Project Review Process (September 1987) and Summary of Monitoring and Research Activities (September 1987). Planned publications are:

- a State of the Estuary report
- a discussion paper on FREMP's public consultation policy
- a status report on water quality

Planned for June 5, 1988 (World Environment Day) is a Fraser River Festival at Deas Island Park. This major event, in cooperation with GVRD Parks, is designed to get the public involved and aware of the Fraser River.

Questions and Answers:

Q. How often does the Management Committee meet?

A. The FREMP Executive Committee meets once a month. The whole Management Committee meets twice a year.

Q. What happens to FREMP after 5 years?

A. There have been preliminary discussions amongst the executive about renewing the FREMP agreement. There has been no clear commitment as yet. I think implementation goes on indefinitely. However it will likely take a different form than the first 5 years. We have created a public expectation about the estuary and there is certainly a demand for information at our office in New Westminster. Whether it gets put into some agency's own department to look after I don't know. I can't give you an answer on that yet.

Q. Are you doing Area Designation work with anyone other than those representing Burnaby?

A. Yes, Delta and Richmond, and we are going to start with Surrey this spring. We have left it up to the municipalities to come forward and volunteer to get involved, except in the case of Surrey. We thought there were some land-use conflicts that needed addressing early on.

2.0 THE GVRD LIQUID WASTE MANAGEMENT PLAN: A Practical Approach to Management in the Fraser River Estuary

H. McConnell, GVRD

H. McConnell outlined the Liquid Waste Management Plan (LWMP) and identified a lack of information available for comprehensive waste management planning.

There are two ways to deal with the current situation: legislate improvement; or rationally plan and priorize improvements. Experiences in Washington State have shown legislation may not be the most effective use of resources (mandatory secondary treatment and CSO/UR controls for the GVRD would cost $1,000 to $2,500 per person). Four steps are recommended: comprehensive environmental monitoring to identify conditions; determine the significant contaminant sources; design programs and facilities to reduce contaminants and improve conditions; implement and monitor the programs and facilities.

Questions and Answers:

Q. In the States, legislation for waste minimization encouraged major chemical companies (3M; Dow) to put in better controls. This often results in dollar savings to the company.

A. There was a lot of information to support the legislation before it was implemented.

Q. Are stormwater and sewage collection systems being kept separate in new developments in the GVRD?

A. Yes. But whether that is good or bad is another question.

Q. We don't have enough information to fully understand the dynamics of pollutants and the levels of pollution in the ambient environment. Does that lack of information extend to what the major sources of pollution are and where we really have major problems in terms of sources?

A. We can easily identify our sources of contaminants as sewage treatment plants, or go to our facilities plans to point out where combined sewer outfalls or storm outfalls are. It's a lot harder to look at non-point sources and find out where those are, and try to quantify the kinds of contamination that those are causing.

Q. How long will it take to complete your program of separating the storm water from sewage?

A. I don't know if that is necessarily going to happen. We have compared the nature of contamination that is coming out of the combined sewer systems in Vancouver, New Westminster and Burnaby, which are the key areas we look at, to the types of contaminant loadings that would come out under a fully separated system. Conditions could get worse with separate sewers than they are now, especially for heavy metals. There is a lot of concern about sewer separation right now on the part of the Plan, and some decisions are going to have to be made on the future of sewer separation as a pollution control measure. It is clear to me that it is not the panacea in answering the pollution question. There may be some areas where it's the most cost-effective way to reduce contamination, but I do not see it as the be-all and end-all answer.

Q. I'm surprised your presentation has left out the magic key words "source control". What is happening with source control and where is it going?

A. The source control program is keyed into the waste management program. In the early 1980's the Regional District got the mandate for regional source control. The first step has been putting together an inventory of the discharges and an inventory of the contamination at the various plants. As part of the LWMP we will be developing guidelines and a draft by-law for the Regional Source Control Program.

Q. Is this a voluntary inventory or is it based on actual monitoring?

A. It is primarily voluntary.

Q. One of the problems with the combined system is that every time it rains, all the lift stations overflow and you get a straight discharge out into the river. It's not only a matter of the concentrations that are being discharged, but you get a complete by-pass of the system.

A. That is only partly true. When you look at a separated storm system, what you say is entirely true, because every drop of rain that runs off into the sewer system goes directly into the receiving waters. When we look at the combined system, we are intercepting close to 50% of the runoff in Greater Vancouver. Only certain rainstorms will cause that system to overflow. So when you take the existing combined system in the Greater Vancouver area and separate it, you close to double the quantity of discharge of urban runoff, not to mention the quality of contamination that you get in there.

R. In a non-separated system, in a big storm event, in addition to the contaminants from the street, you also get contaminants from the sewage and from the industries discharging into the sewer.

A. It's a matter of comparing the quantities and loadings of contaminants. We have done that and although philosophically it doesn't sound as good, realistically when you look at quantities and attach loadings, to separate the system is going to add contaminants to the environment, rather than take them away.

R. Maybe instead of arguing over whether we should have separate or combined systems, we should be talking about increasing the capacity of the system to handle it all.

A. I agree. The issue should be to control the levels of contamination, to protect the environment, to whatever level that needs to be; what we can reasonably achieve, ninety-eight percent control is the $3 billion option.

Q. Whether or not you get overflow depends on how close you are to design load. Have you looked to the future, to operating over capacity, and what will happen then?

A. The Iona plant has been designed to handle combined flow. It will handle ultimate sanitary flow to 2021 or 2036, and will have more than ample capacity to handle combined design flow as well. We can handle 4 times average dry weather flow. The peak sanitary flow that runs through there is something like 1.3 times average sanitary flow. Annacis has been designed primarily for sanitary flow. There is adequate capacity through to 2021 and beyond for sanitary flows and there will be capacity available, although less than at Iona, to handle some combined flow.

Q. Do you have any plans to do what Metro has done in Seattle and get yourself a laboratory to find out who the cheaters are?

A. I don't have that in the plan right now. I think whether or not that happens will come out of the kinds of environmental work and ongoing monitoring work that we need to do to manage the system. I think if we move in that direction we're going to have to make a decision on whether we have a lab like that or not.

3.0 HABITAT USE BY FISHES OF THE LOWER FRASER RIVER:

J.S. Macdonald, Department of Fisheries and Oceans, Biological Sciences Branch

The abundance of several species of fish were monitored monthly or bimonthly for one year at sites near Agassiz and in the North and Main Arms of the Fraser River. The sites were chosen to represent the habitat available to fish in the lower Fraser River. In addition to all species of salmon, many species of non-salmonid were also captured including a variety of sculpins, flounders and shiners. Size

analyses of captured chinook salmon show them to pass through the Agassiz region quickly but to remain for a month or more at the estuarine sites. Chinook left the estuary by early September. Starry flounder are found in the estuary all year but are particularly abundant from April to September.

Adults (75+ mm) are caught from April to June while young-of-the year (15+ mm) appear in June and remain abundant until October. Prickly sculpin adults (35 - 55 mm) were caught from April to July while young-of-the year (30 - 40 mm) appeared in August and remained until October. Other species of fish are being examined and data will be presented during the next year. It is hoped that these data will assist us in describing the residency times of Fraser River fishes and to compare the degree to which different habitat types are used.

Questions and Answers:

Q. Do you have any hypotheses on the differences in numbers of fish caught during low vs. high tide collections?

A. Most of the fish, except stickleback, tend to stay in one portion of the habitat. That is they don't move into the intertidal zone at high tide. Therefore our nets just go overtop of the fish at high tide. This is one of the reasons we did some towing off-shore. We wanted to see if the fish were moving to the centre of the river at high tide as they grew larger. We also checked some of the off-channel sloughs and we were not finding them there.

Q. It was found a number of years ago that pink, chum and chinook move into the marsh areas at high tide and out at low tide. Beach seines at low tide were more productive.

A. This project was designed the way it was because a lot of work had already been done on off-channel habitats. Our work is concentrated in habitats along the margins near the main river channel.

Q. How do you determine residency? Roseberg did work on the Fraser River. At one site he sampled every hour during migration, using a beach seine, and he didn't find any fish. How do you determine whether the fish are resident there?

A. Maybe the use of residency is a misnomer. I should have said timing. Certainly we would like to look at residency times. One of the ways is with tagging. Juvenile fish are very difficult to tag unless you use cold brands. Some of the larger fish were tagged with floy tags. We've had poor recoveries. Ian Birtwell has tagged hundreds of fish, of different species in Deas Slough and didn't get any returns. The question of residency is a real problem.

R. Could you use coded wire tags or fluorescent grit?

A. We've tagged a lot of fish with cold brands but haven't tried grit. I think CWT's are only useful for recoveries in commercial and sports fisheries. You can use 1/2-wire tags to tag smaller fish. Coded wire tagging is awfully time consuming.

Q. With the fish that you think are part of the resident population, did you age them?

A. Not yet. Our first step to looking at ages is just to look at bi- or tri- modal distribution of their size. Hopefully we'll look at some otoliths and do some scale work because that is a key question.

Q. Are those Agassiz chinook overwintering in the Main Stem?

A There is evidence to suggest that they move into the Main Stem in the winter at locations from Agassiz through to the interior. We're not finding fish in the lower parts of the Fraser after September-October.

Q. Are you beach seining the high high and low low tides?

A. We try to. In the summer it's easier to get a high high and a low low tide during daylight hours. In winter if we can't get a high high and a low low, we just pick the best low in daylight hours, which is usually about 11 feet, so it's not very low.

Q. Are you keeping the organs etc. for contaminant analysis?

A. H. Rogers is assisting with the analysis of our fish collected not only from the Fraser River but also from the Homathko River at Bute Inlet. The Homathko River fish will give us baseline contaminant levels for comparison with Fraser River fish.

4.0 THE MOVEMENT OF A POLLUTANT IN THE FRASER ESTUARY AS AFFECTED BY TIDES AND CURRENTS

Anne Woollard, Department of Fisheries and Oceans, Institute of Ocean Sciences

The movement of a chemical substance entering one of the the upper reaches of the Fraser estuary would not only be affected by the riverflow itself, but also by the tide-induced currents. This interaction between tides and river discharge was illustrated by a computer-graphics display of a numerical model, which was earlier developed at the Institute of Ocean Sciences, and subsequently modified to simulate a Lagrangian movement.

A substance released near New Westminster was tracked to Sandheads for both low and high discharge conditions.

Questions and Answers:

Q. We've been out on mostly the North Arm and Main Stem and we've monitored, with a conductivity probe profile or a transmissometer, the tide as it came in. We don't see a salinity front that comes in and forces the fresh water back up. We see a very strong vertical gradient with the fresh water buoyant over top of the salt water. I wonder if this pushing of the fresh water back up actually occurs. Is there some actual data to back that up?

A. When the salt wedge moves in, the surface flow moves faster than what we see here. That's the next phase of the model.

Q. Mostly we see this under low flow conditions but we weren't actually looking for the water going back. There is a very strong vertical gradient, in some cases a sharp discontinuity. You're welcome to our observations, I don't really know what to do with them.

A. The flow that we get, that you saw, is based on differences in height. When we do surface flow, then we have to look at the salt wedge, and you'll see a different picture, especially at low tide.

Q. I can only think of one occasion when the surface flow was altered, so I wondered how often it is, relative to what it might appear to be with the vertical mixing model.

A. We hope to have another film later this year to look at that.

Q. Is dispersion included in the model?

A. No. If we added dispersion it would alter the model.

Q. Do you plan to develop the model further so you can follow the concentration of a substance past a point with time, say at low river flow when there are reversals of tide. How would the concentration at a point vary with time?

A. We don't know how to do it. Maybe in 5 or 6 years from now.

Q. I suppose every time the river backs up like that you're going to get vertical mixing. Have you developed a model to look at that? It would be interesting to see how it affects the food source.

A. Yes. We haven't been able to model that yet.

5.0 BEDFORMS AND BED-LOAD IN THE OUTER MAIN CHANNEL: FRASER ESTUARY

R.A. Kostachuk, Department of Geography, University of Guelph;
J.L. Luternauer, Geological Survey of Canada, Vancouver;
M.A. Church, Department of Geography, University of British Columbia.

Bedforms in the Outer Main Channel between Steveston and Sand Heads were monitored with echo-sounders. Changes in bedform height and length follow, but lag behind, seasonal fluctuations in river discharge. Migration rates of bedforms respond more directly to river discharge. Bedform characteristics were utilized to estimate bed-load transport in the estuary and a strong, direct relationship was found between bed-load and river discharge. Bed-load transport in the estuary appears to occur at lower discharges than in reaches upstream, possibly because of an increase in sediment

movement along the bed to compensate for a reduction in suspended bed material load produced by the salt wedge.

Questions and Answers:

Q. Is there any information on how the particle size of the bed changes over time?

A. We took 20 samples along the estuary between Sand Heads and Steveston on 5 different occasions between April and September. We found no change in the grain size in the estuary over that time period.

Q. What was the grain size?

A. It was all around the boundary of medium to fine sand.

Q. Does that mean the bed is moving en masse out of the river, or is it being selectively washed out?

A. There are indications, from other results, of a decrease in grain size as you go downstream from Agassiz. There is no change in grain size in our results, so yes it is moving en masse. The material in the bed is not necessarily moved as bed-load in these dunes. It is also moved in suspension, especially as the tide falls and the current accelerates. We have information on the suspended load also, but I did not present that today.

Q. What causes hysteresis? (time lag)

A. The bedforms take time to adjust to changing flow conditions. There is an analogy being used for biological populations in that the larger bedforms tend to be replaced by smaller ones. It just takes time for that to be accomplished.

Q. Is there a way to predict if you were to dump a truck load of sediment at one point, how long it would take to get out the end of the estuary?

A. Bed-load moves very slowly. If our average bedform migration rate is 25 m/day over freshet period, then over 90 days it's not going to move very far.

It turns out that bed-load only moves significantly during freshet period. It may only move a couple of kilometres.

Q. Have you been able to come up with the magnitude of bed-load transported over the freshet period?

A. I haven't made any estimate of the total magnitude moved over that period.

Q. Can you estimate the order of magnitude moved over a year?

A. I don't know.

Q. Do you have an estimate of the sand transported in suspension in comparison to bed-load?

A. Because of limited information on bed-load, we only had 4 days where we had both the suspended load and bed-load estimates. It turned out that the bed-load during early June was about 7% of the total (combined bed-load and suspended). In July it was about 3.4%, according to our estimate. We couldn't break it down into grain size fractions because we didn't have the grain-size information.

Q. Where is all this material ending up? Is it all raining down on the outer estuary once it gets out of the River, or is it being carried further than that?

A. We did some surveys at the mouth of the River with J. Luternauer using a variety of geophysical techniques. There is a submarine canyon at the mouth of the River and it appears that this material, once it makes it to the mouth of the River, builds forward over a period of years, and then there is a fairly large scale landslide and the material is transported seaward. We have information that it gets at least 5 - 7 km out into the Strait of Georgia, transported within this submarine canyon.

6.0 FRONTS ASSOCIATED WITH THE FRASER RIVER

J.S. Stronach, Pacific Ocean Sciences Ltd.; and
T.S. Murty, Department of Fisheries & Oceans, Institute of Ocean Sciences.

Observations and theoretical speculations on fronts within the Fraser River, on Roberts Banks and in the Strait of Georgia are presented. These observaions will be discussed in light of the buoyant spreading upper layer model GF4, which permits one-way interaction, i.e. the lower layer influencing the dynamics of the upper layer, but not the opposite situation. Presently there are plans to develop a two-way interactive model GF9 which will have provision for inclusion of fronts.

Questions & Answers:

Q. Do you have any evidence that the front is moving down into Puget Sound? Can you predict that from the work you've done?

A. Certainly silty water moves down as a diffuse front. You can see some sediment. The way the river comes out and the phase of the tide, generally you don't have a front down there, you have a sort of weak advection of sediment into that area.

Q. Have you done any studies on how the dynamics of the front affect the biota?

A. D. Mackis is one person, and I know that's not exclusive, who is looking at zooplankton and phytoplankton. There are a lot of indications the front is an area of interest to zooplankton and phytoplankton distributions.

R. Mike St. John at U.B.C. is looking at biological fronts. He is starting this summer to work on the Fraser River.

7.0 CONTAMINANT LEVELS IN SEDIMENTS OF THE FRASER RIVER ESTUARY AS A MEASURE OF LOCAL AND UPSTREAM CONTAMINATION

Michael Waldichuk, Department of Fisheries and Oceans,
Biological Sciences Branch, West Vancouver Laboratory

Up to 2,000,000 cubic metres of sediments are dredged annually in the Main and North Arms of the Fraser River to maintain channels deep enough for navigation and to deepen log ponds and wharf areas at forest products operations. Applications for disposal of the dredged material at the Point Grey and Sand Heads dumpsites, or at points downstream in the river, are reviewed by the Regional Ocean Dumping Advisory Committee (RODAC) for the Pacific/Yukon Region. When it is considered desirable, analyses of the sediments to be disposed of are requested by RODAC to determine if they meet regulatory limits under the Ocean Dumping Control Act (ODCA). The concern is mainly about so-called Schedule I substances, which are prohibited, except in trace amounts. These include, among others, mercury and cadmium and their compounds, petroleum hydrocarbons, and organohalogen compounds. The maximum concentrations, defined as trace amounts under the Act, are 0.75 mg/kg for mercury and 0.60 mg/kg for cadmium in the solid phase, 10.0 mg/kg n-hexane soluble oils and greases, and 0.01 part of the concentration of organohalogen compound shown to be toxic to marine organisms in a standard bioassay test. In general, sediments transported from upstream and deposited in the Fraser River estuary exhibit concentrations of Schedule I substances within the regulatory limits for ocean dumping

under the ODCA. However, sediments contaminated by local activities, e.g. ship-building, in the estuary, may exceed these limits.

Questions and Answers:

Q. Are the arsenic levels at shipyards due to a build up from bottom paint?

A. We are uncertain where the arsenic originates. Bottom paints are an important source of copper; some zinc stems from zinc plating, and chromium can be fairly high, possibly from chrome plating. We have had problems with high metal concentrations in sediments in the areas of shipyards in Burrard Inlet. They are often high in mercury and cadmium. We haven't encountered this in the Fraser River, fortunately. That would present some big problems for ocean disposal under the Ocean Dumping Control Act. It would have presented even bigger problems if these metals were high in sediments carried downstream from upstream sources in the Fraser River, because of the volumes involved.

Q. Is there any move towards setting up Schedules for dangerous organics such as dioxin.

A. The Schedule I lists only organohalogens among the dangerous organics, in addition to petroleum hydrocarbons. We're dealing in that sense with dioxins because they do have chlorines attached. There would be prohibition of high levels of dioxin, but it is based not on concentration in sediments, but rather on bioassay. It must not exceed 0.01 of a bioassay concentration for acute toxicity given by a 96-hour LC50. So we're dealing with concentration based on acute bioassay rather than on absolute concentration.

Q. What does the developer do when he is faced with these high levels, some that exceed your concentrations, and how deep within the sediment do many of these metals go?

A. Some of these sediments with quite high contaminant concentrations may go down several metres. Usually, if it is a case of local development or operation of comparatively recent history, the concentration is fairly shallow. There is a

particular site of a former creosote operation, at Koppers International Canada Ltd., on the North Arm, that had concentrations of 50,000 ppm creosote in sediments at 5 m depth. This is where they had been treating timber, and the creosote penetrated down to depths of 5 - 10 metres in the sediments. RODAC concluded the dredged material could not be dumped at sea. The only thing that could be done was to take out the highly contaminated sediments and incinerate them, or entomb them right there, but seal them in so that they could not leach out into Fraser River water.

Q. If you were going to be dredging out several cubic metres of sediment, how do you take a representative sample of that for analysis?

A. This is something we've been wrestling with right along. There are all sorts of statistics offered on the way sampling should be done, to assure that you have a representative sample. To some extent, in practice, it's guess-work. You take cores at a number of places; we usually ask for 2 samples, appropriately spaced. Sometimes, it may require 4 samples if there is a large area to be dredged. The cores are analysed according to 5-cm sections, and we look at core data to decide what we're going to recommend for disposal. In some cases, the upper layer of contaminated material has to be disposed of in other ways than ocean dumping. The deeper, relatively uncontaminated sediments can go to the Point Grey dumpsite, or some other ocean dumpsite.

8.0 DETERMINING SAMPLING PROTOCOLS FOR SEDIMENTS IN THE FRASER RIVER

L.G. Swain, Ministry of Environment and Parks, Water Management Branch
D.G. Walton, Ministry of Environment and Parks, Waste Management Branch

Ten consecutive replicate sediment samples were collected from two sites in each of the Main Stem, North Arm and Main Arm of the Fraser River during January 1987. These sites had been selected on the basis of the ability to

simultaneously obtain benthos samples. Sediment samples were analyzed for grain size, volatile residue, moisture content, selected metals and nutrients, chlorophenols, PCBs, and pesticides. The chlorophenol, PCB, and pesticide values were too low to be examined using a statistical procedure. Using a statistical procedure (F test:P=0.05), it was determined that, for almost all characteristics at the six sites, the accuracy of the estimate of variability was not improved significantly by analyzing ten replicates versus three.

The statistical procedure (F test:P=0.05) was also used to determine the upstream/downstream variability of these characteristics between the two sites on each reach. Depending upon the characteristic, the variability between upstream and downstream sites was often statistically significant.

In addition to the replicate sampling, five random sediment samples were collected coincidently from each reach. Values for characteristics measured in these samples were often outside the ranges of values for the replicate sites. Therefore, the variability of most characteristics along the three river reaches was significant either statistically or intuitively.

Inter-site variability seems to be a more important

concern than intra-site variability. It is therefore recommended that future sediment monitoring programs should make use of more sites in each of the three river reaches. This can be accomplished with minimal increases in analytical cost and no decrease in statistical reliability of the data by reducing the number of replicate samples collected from each site.

Questions and Answers:

Q. Were you analyzing the fines fraction or the total sample?

A. The total sample.

Q. What sort of concentration were you getting in the sediments? You've done some analyses, mainly chlorophenols, tetra, PCB?

A. For chlorophenols and tetra, almost all were below detection. I don't think that's something we should be overjoyed with. When we were doing some work in 1985, we were getting some finer particles than we found at the same sites this year, and we did find chlorophenols. It may be a relationship with the particle size we were sampling.

Q. How did you take your replicates?

A. At the replicate sites we took 10 grabs with the Peterson and took 10 sequential samples from there. Then we used the rest of the grab to look for the benthic material.

Q. Did you measure the organic content of the sediments?

A. Yes.

9.0 THE USE OF THE PANAGRELLUS REDIVIVUS NEMATODE BIOASSAY TO EVALUATE THE TOXICITY OF BED SEDIMENTS FROM THE LOWER FRASER RIVER

T.M. Tuominen, Inland Waters Directorate
L.M. Churchland; B. Dutka; A. Jurkovic and
C. Baldazzi.

In June 1987, a survey was conducted from the Fraser River estuary to the headwaters of the Fraser River to evaluate the use of various toxicity and microbiological tests as screening tools to comparatively assess the aquatic quality of the water and sediment. Sites expected to contain deposits of fine sediments were selected. The results of one of the toxicity tests, the Panagrellus redivivus nematode bioassay, will be discussed.

This bioassay was conducted on extracts of bed sediments which were collected from eight sites in the lower Fraser River. One subsample of each sediment sample was extracted with water; a second subsample was extracted with methanol. Other subsamples were tested with other microbiological and toxicity tests, analysed for TOC and particle size, and reserved for chemical analysis if toxic effects were detected. In the nematode bioassay, organisms were exposed to 10% dilution of the water extract (1 part extract: 9 parts media) and a 3% dilution of the methanol extract (3 parts extract: 97 parts media). The following three distinct types of toxic effects (in order of severity) are detected by the bioassay: lethality, inhibition of growth and inhibition of maturation.

The bioassay results indicated the following: i) most of the samples resulted in no toxic effect, ii) significant toxic responses were detected in four out of four samples collected from McDonald Slough, two out of four samples collected from the southwest shore of Mitchell Island, one out of 4 samples collected from the Main Arm (by the Chatterton Petro Chemical Corp. plant site) and one out of four samples collected from the southwest shore of Annacis Island (near Purfleet Pt.), iii) where an effect was detected, the water extract was more toxic that the methanol extract. When data become available, the results of the nematode bioassays will be compared to the results of the other toxicology tests and evaluated with respect to the concentrations of selected metals in the sediments.

Questions and Answers:

Q. Do you feel the nematode is better than the amphipod bioassay?

A. I don't know anything about the amphipod test. From talking to M. Samoiloff, his results to date show the nematode bioassay is more sensitive to organic contaminants than Daphnia, but Daphnia seem more sensitive to metals. The nematode is more sensitive to metals than microtox. These are the first nematode bioassays we've had done and I have no information on amphipods to compare to these results.

Q. What do you mean by 10% water extraction?

A. First the sediment was extracted at 1 g sediment to 9 parts water. After the extraction process, they then diluted 1 mL of the extract with 9 mL of media, resulting in a 10% extract.

For the methanol extract they originally took 5 g sediment with 5 g methanol for a 1 to 1 extraction, which is more concentrated, and was then diluted by 3 parts methanol extract to 97 parts media. So the concentrations are not exactly equal, but they're fairly close.

Q. Could there have been a salinity effect?

A. I don't think there could have been very much with the dilution it goes through. When you look at the end product, the sediment was diluted by 100. This worm is fairly insensitive to a high range of salinity and pH, and when they were tested by Samoiloff and associates, along with marine nematodes, they found that at high salinity the growth of Panagrellus would be inhibited, but the salinity would not have a lethal effect. McDonald Slough would be the most saline station.

Q. Is a report available?

A. It is in progress. B. Dutka is working on a report for the other bioassays.

Q. We would regard McDonald Slough as being more pristine than the other sites looked at, and yet it seems the most lethal effect is being picked up there. Could it be that the decaying woodwaste from booms being kept in the slough is responsible for the toxic effect?

A. It's possible. We don't know. I would have expected the sediment from the area around Mitchell Island to have a more toxic effect.

Q. Is it difficult to conduct the bioassay? Could you do it in-house?

A. I think one should be able to set it up. It involves microscopic work. It's a matter of growing the worms and getting the media set up. The lab we used has developed a sensitive strain of worms which he uses for the bioassays.

Q. Could one get some of the sensitive worms from him?

A. I don't know.

Q. What is the cost involved?

A. It cost us $60 a sample. It's not bad compared to organic analysis. That's what we wanted, something as a preliminary screening test to find out where the toxic conditions are, so you can then do your more expensive chemical analyses.

R. We have used this test on the North Saskatchewan River, combined with some test of fractionation of the organic analysis of the sediment. The toxicity shows up in the fraction containing oxygen-containing compounds, and not with the priority pollutants and organochlorines. Our analytical standard with priority pollutants is negative. The toxic components may not be what you think.

10.0 MODELLING TOXIC CONTAMINANTS IN THE FRASER RIVER

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One of the difficulties of setting up a water quality monitoring program for the Fraser River is the detection of trace organic contaminants such as chlorinated phenols with adequate temporal and spatial sampling coverage. The discharge of chlorinated phenols is often sporadic and the cost of the chemical analysis is expensive. Since aquatic organisms tend to bioconcentrate these toxicants in proportion to the levels in the environment, an understanding of the pathway and transport of the contaminants in the river system is needed.

Following two intensive sampling experiments in June 9 - 12 and November 23 - 27, 1986, we adopted a modelling approach to study the physical and chemical interaction for

the chlorinated phenols. We used the computed hourly flows and water levels from a one-dimensional tidal flow model (Ages and Woollard, 1986) for the Fraser River estuary from New Westminster to the river outlets including all the river branches. Comparison of the computed flow with the drogue data showed a relative error of about 15 to 25%. These computed results were used in a toxicant transport model (TOXRIV) to simulate the movement and transformation of chlorinated phenols.

In the TOXRIV model, the river was divided in 55 segments. For each segment, the model included the advection of both suspended sediment and chlorinated phenol concentrations, the adsorption/desorption mechanisms based on known partition coefficients, the settling of the suspended sediments and the degradation of the chemicals. It was found that by adjusting the loading estimates, the computed concentration could be brought to within a mean relative error of about 15 to 30% as compared to the observed 2,3,4,6-tetrachlorophenol concentration. A dilution constant was also needed to account for the fully mixed condition in the river segments in relation to the single point measurements used in the fixed station and drogue data.

On the whole, the model results seem to augment the data gaps and help the data interpretation. For high flows, as in the June episode, both the computed and the observed results showed dominantly downstream transports. For low flows, as

in the November episode, both results showed occasional upstream pollutant transports due to tidal effects in the North Arm. The model was implemented in a user friendly format for use in an IBM/AT microcomputer with colour graphic display of the time and space changes in the concentrations. However, more data are needed to confirm the model performance.

Questions and Answers:

Q. In looking at the loading estimates, did you try to correlate those to climatic conditions, such as rainfall periods to see if there was a relation to land runoff?

A. We have made no conclusions yet. Half are correlated and half are not.

Q. You mention you have a model in Ontario.

A. Of course there is no sea in Ontario. I'm talking about the Kaministiquia River which empties into Lake Superior. We think because of the upwelling it brings up the deeper water into the river. The water is warm and stratified. You can see the kinds of loadings and model that Jim Stronach was talking about.

Q. I'm not clear on your application with sediments. How did you move your sediment in the model? Was it a local dispersion that you superimposed on the model?

A. I had to solve the sediment transport problem first. You have dispersion after using the computed transport, as well as settling and suspension of sediments, which is by itself a model. We have the dissolved chlorophenols, adsorbed and desorbed. The sediment and the total, adsorbed and desorbed chlorphenol are the four unknowns for the four equations.

Q. If you put the fine sediments in you get 2 dimensions and you have a totally different situation.

A. I don't know if it's totally different, but I think with both kinds there we probably see more of the same phenomenon. You can make it so complicated, in terms of dimensions that you can include, phytoplankton, bacteria, etc. There is a fine line whereby our model has immediate practical use and the other side is the fun of it, for research.

Q. Is the model available?

A. Yes, but lots of areas need to be tidied up first, and for demonstration only. If we want other days we need to go to Al Ages for the tidal computations.

Q. Is there a paper coming?

A. We have a paper coming in April or so.

11.0 TOXIC CHEMICAL ACCUMULATION IN THE AQUATIC VASCULAR PLANTS OF THE FRASER RIVER ESTUARY

Anne I. Moody, AIM Ecological Consultants Ltd., Aldergrove, B.C.

Coastal submergent and emergent vegetation has long been identified as irreplacable fish and wildlife habitat. Few studies have focused on the effects of chemical accumulation in the coastal vegetation, but have concentrated on the physical environment and middle trophic levels, ignoring the link between the two. Monitoring of water quality near industrial sites often reflects conditions when the sample was collected. Winds, wave action, currents, and river flow influence the dispersion of contaminants. The fauna exposed to contaminants are mobile and tissue analyses are difficult

to interpret. The presence of algae have shown the level of contaminants in their immediate environment. Vascular plants can reflect conditions in the water column as well as substrates.

The high annual productivity of intertidal marshes makes them a vital component of many food webs since all parts of the plants may be consumed by small mammals and waterfowl. As the plants decay during the fall and winter, the resulting detritus is consumed by bacteria, invertebrates and fish. Mercury and lead can accumulate in plant tissues and enter the food chain. Cadmium, copper and zinc may be toxic to the plants and can be passed on to other organisms. The fate of organic pollutants such as PCB and PCP within the vegetation is poorly known. Heavy metals such as mercury have an affinity for organic particulates, so in many instances the organic detritus becomes enriched with metals as it is washed around in the estuary or when it lies on contaminated substrates.

Our study of mercury accumulation in the vascular plants of the Squamish River estuary showed that mercury was accumulated to different degrees in the various plant organs. It also became apparent that the plants absorbed mercury from the root and rhizome depth of the substrate, translocated it to the above ground plant components and finally deposited it on the marsh surface as the above ground tissues were broken down.

AIM Ecological Consultants Ltd. have initiated a study to examine the levels of specific contaminants in the Fraser estuary. In September 1987 and February 1988 water, sediment and plant samples were collected at 4 sites across the Fraser estuary. In the fall, above ground and below ground plant components were collected and analyzed. In February, only below ground components were available. The sampling will again be repeated in June 1988 when the plants are at their maximum above ground development. The objectives are to determine where toxic materials are being stored in the plant and at what levels.

A separate component of the study involved determining the effects of high levels of contaminants on "clean" plant material using greenhouse grown marsh species. Use of these species will enable us to measure the background contaminant levels of hydroponically grown plants and based on this knowledge, determine the rate of uptake of contaminants when the plants are moved into a contaminated environment. Various contaminants are also being introduced into the hydroponic solution to enable evaluation of the rate of uptake of known concentrations of contaminants.

Preliminary results from the September sampling indicate that cadmium levels in sediments were higher at Woodward Island and Reifel Refuge than at either Richmond or North Arm sampling locations. The opposite was true for mercury, copper, lead and zinc. As the plants were sampled very late

in the growing season it is difficult to evaluate any patterns from the results so far. However, indications are that there are strong differences between species. Carex lyngbyei roots contained copper at levels equal to or in excess of those detected in the sediments. Scirpus americanus collected from the same area contained copper at less than 9% of ambient sediment levels while Scirpus validus contained copper at roughly 50% of the sediment levels. A similar pattern was observed for lead. Results from the analyses of the organic contaminants showed the PCB's and PCP's were being accumulated in plant roots at much greater levels than in the sediments. In some cases even the shoots indicated higher levels than the sediments. PCB levels in Scirpus validus roots were a maximum of 0.13 ug/g while maximum levels in shoots were 0.03 ug/g. Sediment samples were all less than 0.02 ug/g.

Questions and Answers:

Q. What kind of extraction are you using?

A. A.S. Lab are doing the extractions, it's the same method as sediment extractions.

Q. Have you been able to compare your results using vascular plants to what some investigators are getting with seaweeds without roots? They seem to be getting higher levels in leaves.

A. We are looking at comparisons. We just recently received these results and haven't had a chance to do a lot with them yet. Certainly that's something we want to look at, to examine how the algae compare with the vascular plants and evaluate whether the plants are taking the material from the water or from the sediment. The higher levels in the roots would indicate they are absorbing

through the roots, and that's generally been the path for vascular plants to absorb materials.

Q. One of the problems in looking at plants is a lot of fine sediments adhere to submerged parts, especially at freshet. We use ash free dry weight to get away from trying to scrub off sediment. What did you do to ensure no sediment was introduced to the analyses?

A. They were repeatedly washed under a spray jet. From our Squamish Estuary work we concluded roots can't be washed clean enough, but with rhizomes, they have a fairly smooth surface and they can be washed quite clean. We also compared our results to ash free dry weight and there was not much difference. When there was a significant difference, we have noted it. There is a very consistent pattern between the concentration of materials in the shoots and in the roots, the pattern is very easily documented.

Q. In your September sample, translocation for storage in the roots in fall may have influenced the concentration in the rhizomes.

A. We didn't intend to sample in September, but that's when the contract got going. Hopefully the sampling in June will give a better indication of the breakdown between above ground and below ground components.

Q. Were the stems exposed to air?

A. They would be exposed to air and because they are intertidal. They would also be exposed to water.

Q. Being exposed to the air, you couldn't really rule out deposition of material, various heavy metals, coming from the air.

A. Not really, except that they're washed by the tides every day.

Q. For terrestrial plants there have been studies showing that even with thorough washing, for some metals such as lead, at least 50% will remain attached to the vegetation.

A. I don't know how much of that would adhere, a lot of these plants have a fairly heavy silt load on leaves which blocks off a lot of material coming in from the air. It may be a consideration, but I can't evaluate how great. I don't think it's anywhere near as great as with terrestrial plants that don't have the silt coating and aren't washed every day.

Q. A review that we did recently indicates there can be selective translocation of various metals adsorbed through tissue to various parts of the plant, so it's hard to rule out that the heavy metal concentration in the roots is coming in through the water.

A. I can't break down between the two. This is something that's never been done before, so we're getting a first cut at trying to evaluate if there are different concentrations and which contaminants are being accumulated by plants, and where they are, in the shoots or roots.

Q. Some questions should be answered by the hydroponics experiment.

A. We're trying to sort that out through the hydroponics. At least that way we'll have a known concentration of contaminant introduced to plants and we'll be able to see how that level relates to the sample results.

12.0 CHLOROPHENOLS IN THE FRASER

J. Carey

No Abstract submitted.

Questions and Answers:

Q. Are you using PCP as the standard for both trichlorophenol and tetrachlorophenol? I think you'll find with the curve for the actual compounds that 3,4,5 trichlorophenol predominates over tetrachlorophenol in fish and in the River itself.

A. If I had to predict a response factor relative to PCP I would have said about 0.6. I realize I used PCP but that just means these concentrations were about 60% of what they should have been, and were actually underestimated. Without the standards I had to pick something.

Q. You were doing your analysis during a high flow period with a high sediment load. Do you find the sediment affects recovery of PCP?

A. These were all filtered samples.

Q. Did you look at the particles associated with the sediment, or were you doing dissolved?

A. Strictly dissolved. We've collected sediment in sediment traps and we're looking at the partition coefficient now. The binding isn't very strong, in the sediment collected for centrifuge, there is only 3% organic carbon. It's quite minimal, and the partitioning of contaminants in general, especially the ionized contaminants, I really don't think chlorophenols are going to be strongly partitioned.

Q. Even though the mills were on strike, there would be some mills using chlorinated phenols still operating. Even those sites not operating could have leaching from stacked lumber during heavy rainfall.

A. A few were operating. I think the stacked lumber is the source. P. Krahn has the data for that. Either it's the storm sewer system or it's contaminated rainfall, immediate leachate. These data show it is significant and can't be ignored.

Q. Where did you get the objective of 200 ppb chlorophenols?

A. It's a Provisional Provincial Objective. I wouldn't want to defend it. If it is the objective, it's being exceeded.

13.0 BIO-ACCUMULATION OF CHLOROPHENOLS IN SALMON IN EARLY STAGES

James A. Servizi, Dept. of Fisheries and Oceans, Cultus Lake, B.C.
Robert W. Gordon and John H. Carey, Canada Centre of Inland Waters, Burlington, Ontario.

Bio-accumulation of chlorophenols was studied in laboratory exposed and feral pink salmon (egg to fry) and fingerling chinook. Pink salmon exposed in the laboratory from egg to fry to ug/l amounts of mixed chlorophenols bio-accumulated tetrachlorophenol (TeCP) and pentachlorophenol (PCP) in a ratio similar to the dose. Fingerling chinook exposed in the laboratory at 0.7° C for 62 days to similar doses bio-accumulated pentachlorophenol preferentially.

Emergent pink fry collected from spawning grounds contained variable amounts of chlorophenols. Amounts were greatest in fry from the Thompson River where values were 12.5, 5.8, 28.5 and 11.6 ng/g for TeCP, PCP, trichloro- and di-chlorophenol, respectively. Minimum amounts (0.8 ng/g PCP) occurred in Sweltzer Creek pink salmon fry. Fingerling chinook salmon collected from the Fraser River averaged 7.6 and 24.4 ng/g TeCP and PCP, respectively.

Graphical analysis of PCP content of experimental and feral specimens along with data from other sources yielded a log/log regression with concentration of PCP in the ambient water.

Questions and Answers:

Q. Is TCMTB better or worse than chlorophenols or do we know enough about the effects of it?

A. We don't know very much about the TCMTB. We do know it's lethal to fish. It won't have dioxins, I guess that's a plus.

Q. Do you have any idea about the rate of uptake by fish in relation to age.

A. We didn't measure uptake rates. There have been uptake rates studies done in the literature.

Q. I'm thinking of the chinook and the fry that live in the Fraser, how much increase would there be in the tissue, for the length of time they are there?

A. What we see is that they relatively quickly reach equilibrium with the environment. It doesn't keep increasing. The exposure we had for chinook was 62 days. The exposures in some other studies were shorter. There are papers on PCP and uptakes that indicate it would take a few days to reach equilibrium with the water. These studies suggest fish reach equilibrium with their environment and that's the level you see.

Q. Did you look at the concentration of phenolics in the egg and sperm?

A. We only looked at eggs and only in the two samples I showed, where it ranged from 0.2 to 0.3 of ng/g of egg.

Q. Did you do any depuration studies?

A. Not on these. There have been depuration studies done.

Q. Did you look at background levels of chlorophenols in the feed?

A. We didn't feed them. The juvenile fish, at the stage of life they were, at a temperature of 0.7 C, would be in an overwintering situation where feed is not necessary. They probably would eat something if you gave it to them. We monitored these fish for their weight and length, and lipid and protein content. The eggs from fish to fry, don't feed either. They're growing on their yolk sac, so they get their chlorophenol either entirely from the yolk or they take it in from the water. From these data we would conclude the alevins (sac fry) and juveniles can take up chlorophenols directly from the water as a major pathway.

Q. Did you see an effect on the egg or fry from the concentrations to which you exposed them?

A. There were no mortalities. There was no effect that we could measure on weight from egg to fry. There was a small difference in lipid content. For juveniles there was no effect that we could measure in lipid, protein, condition factor or weight. For the egg to fry there is a little difference in lipid content based on the samples we had, but they were composite samples so we don't have a statistical basis for comparing those 3 groups. The trend would be explainable by our understanding of the impact of chlorinated phenolics as uncouplers of oxidated phosphorylation. So you could expect to have possibly lower fat content if that's the only source of energy, which it is with an egg. We don't have data to confirm this effect, however.

Q. The values you have for both natural and test concentrations, are they for the whole fish? How many fish would you analyse to come up with those numbers?

A. The values are for the whole fish. A lot of fish are represented by each sample. The pink were a composite of 50 alevins, the two chinook samples were 11 and 22, respectively. I don't remember the number of rainbow trout used by Niimi, but it was several fish.

We can't do statistics on the pink fry because we don't have individual analyses. Individual analyses of very small fish are not feasible.

14.0 ASSESSMENT OF STORM WATER RELATED CHLOROPHENOL RELEASES FROM WOOD PROTECTION FACILITIES IN BRITISH COLUMBIA

P.K. Krahn, Environment Canada
J.A. Shrimpton; R.D. Glue, Environment Canada

This report documents the contamination of storm water runoff with chlorophenols leached from surface treated lumber in British Columbia. Storm water runoff from sawmills and lumber export terminals was suspected as a significant source of chlorophenols to adjacent water courses based on a 1978 Environment Canada Study. During 1986 and 1987, a four month field study was conducted at five sawmills and two lumber export terminals. The sites represented typical lumber handling and treatment methods including dip tanks, low pressure and high pressure spray systems. Leachate dripping directly from the wood and yard runoff was analyzed for 2,3,4,6-tetrachlorophenol and pentachlorophenol using a gas chromatography method.

It was found that leaching from treated lumber began after 1.0 to 1.5 mm of continuous rainfall. Dip treated lumber leached up to 158 000 parts per billion (ppb) and generated runoff with up to 6 600 ppb total chlorophenols. Low pressure sprayed lumber leached up to 576 000 ppb total chlorophenols. High pressure sprayed lumber leached up to 9 800 ppb and generated average yard runoff up to 1 968 ppb total chlorophenols. Chlorophenols were found to leach from treated lumber under all conditions of exposure to rainfall. Conditions studied included up to eight days of drying, 13

consecutive days of rainfall and 18 days of alternating wet and dry periods.

Most lumber storage yards have their own drainage systems which discharge directly to fresh or marine waters. Acute lethal static bioassay tests (LT50's) using rainbow trout underyearling were performed on two pure stormwater samples discharging from such yards. The fish became excited upon introduction to the effluent, exhibited coughing and erratic swimming within 10 minutes and mortality in all fish occurred within 40 to 120 minutes. The acute lethal toxicity for salmonids of 32 to 130 ppb total chlorophenols was exceeded virtually 100% of the time at all the storage yards monitored.

Questions and Answers:

Q. You've convinced us where the chlorophenols are coming from. Now what kind of political action is going to be generated?

A. When my study was released, E.P. and W.M.B. also released interim levels to be permitted in storm water, 10 ppb for chlorophenols, 5 ppb TCMTB and PQ-8. The mills have about a year to implement controls. By next September they should be meeting these levels which means they're going to have to comply with the Code and then some. I have done an Environmental Assessment of Lower Mainland mills which will be released soon.

We came to realize the psychology of the mills is to meet production quotas, so the cleanup gets low priority. Even though they have the Code, it didn't seem very effective. I developed a comprehensive questionnaire to assess the mills, which was tested on 30 mills. We will be taking this stormwater slide show and another to the eight regions in the province, and will be holding seminars. The mill managers and operators, will be attending, as well as Waste Management personnel.

We will show that chlorophenols kill fish. We will also show them the practices that are currently being carried out and what not to do. We will give them a copy of the questionnaire to take to their mills and say take a look around, because in a couple of weeks we'll be around to assess your mill. They have that grace period to clean up their act and to get their environmental repairs into their budget. A lot of them don't have an environmental budget.

Another typical attitude was "we don't really want to use this stuff so we don't have to be responsible for it. We just use it because we have to."

An example at one mill was they knew they weren't allowed to throw heavily contaminated sludges onto pulpmill shavings, so they took the sludge out of the spray box, put it in a tank that had a screen on the bottom, took a garden hose and thoroughly flushed it. The filtrate went down into the storm sewer. Now they had low-level contaminated sludges that they could throw onto the pulpmill shavings.

A real re-education process has to go on. There is also enforcement through the Fisheries Act if problems arise. Hopefully the Province is going to be setting some good levels, and carrying out monitoring as well.

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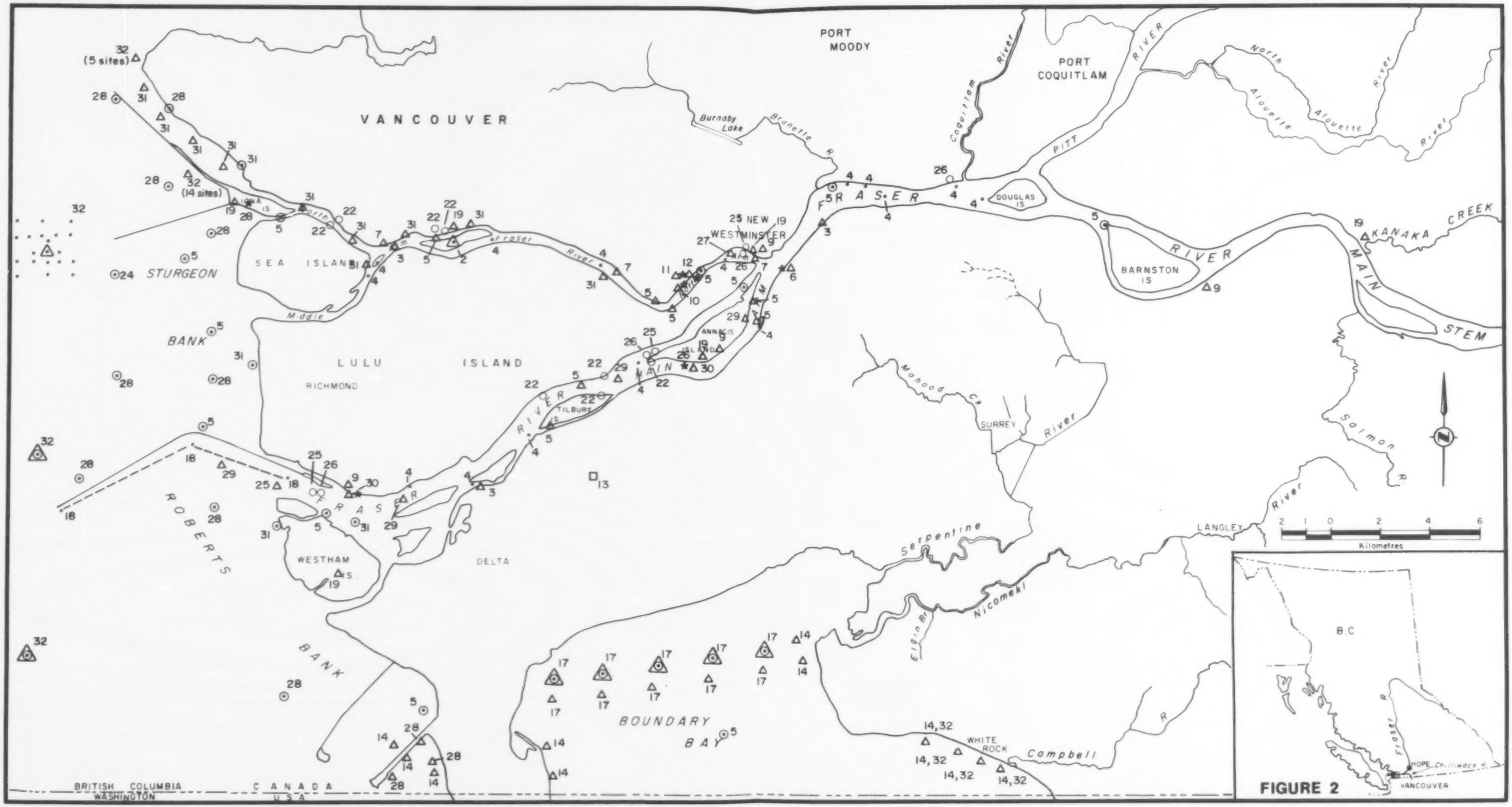

FIGURE 2

LEGEND

- Sediment
- Water
- Biota
- Biota and Sediment
- Water and Sediment
- Bioassay
- Groundwater
- Water , Biota and Sediment

MONITORING IN THE FRASER RIVER ESTUARY (1988 QUESTIONNAIRE INFORMATION)